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350227-008

20 December 2011

**Re: Technical Memorandum**
**Responses to Environmental Assessment Scoping Comments on Denison Mines (USA) Corp. La Sal Mine Expanded Plan of Operations**

## SECTION 1

## INTRODUCTION AND PURPOSE

SENES Consultants Limited (hereinafter called SENES) was requested by the U.S. Bureau of Land Management to address radiological health, safety and environmental questions and comments that were raised as part of the scoping of the Environmental Assessment ("EA") accompanying the expanded Plan of Operations for the La Sal Mines Complex in San Juan County, Utah.

SENES has provided our response in the form of a Technical Memorandum and supporting documentation. The Technical Memorandum is organized as follows.

Responses to those EA scoping comments which related to radiological issues are provided as outlined in Section 2 below.

- Section 2, 1.0 Responses to agency scoping comments on the La Sal EA relating to Air Quality;
- Section 2, 2.0 Responses to agency scoping comments on the La Sal EA relating to Radiological Issues;
- Section 2, 3.0 Responses to agency scoping comments on the La Sal EA relating to Radon;
- Section 2, 4.0 Responses to agency scoping comments on the La Sal EA relating to Soils;
- Section 2, 5.0 Responses to agency scoping comments on the La Sal EA relating to Unnecessary or Undue Degradation;
- Section 2, 6.0 Responses to agency scoping comments on the La Sal EA relating to Water;

- Section 2, 7.0 Responses to agency scoping comments on the La Sal EA relating to Wildlife;
- Section 2, 8.0 Responses to agency scoping comments on the La Sal EA relating to Worker Health and Safety;
- Section 2, 9.0 References.

Figures are following the text in this memorandum

Material supporting the responses is provided in Attachments A, B, C, and D as identified in the responses. Attachment A contains a statement of SENES expertise and qualifications to address the radiological comments raised during the EA scoping. Attachment B contains a summary of other current or reasonably foreseeable future uranium and non-uranium operations in the region surrounding the La Sal Mine Complex. Attachment C contains details of an application of the MILDOS-AREA model to establish the dose to a receptor continually exposed airborne uranium ore dust after a 40 year period mine operation and ongoing deposition from air to soil. Attachment D contains details of a bioaccumulation of uranium deposited in the soil horizon after a 40 year period mine operation and ongoing deposition from air to soil.

Comments related to non-radiological issues or effects have been addressed by others and are not incorporated in this Technical Memorandum.

## SECTION 2

## RESPONSES TO AGENCY SCOPING COMMENTS ON THE LA SAL EA

### 1.0 AIR QUALITY

*1.1 Are hazards present caused by emission of radioactive and non-radioactive particulates from the mine vents?*

Radioactive Particulates

Two types of radioactive particulates are emitted from mine vents: particulates generated as radon decays into its progeny, or daughter products, and particulates associated with uranium ore dust. As shown in Figure 1, uranium-238 decays from the parent uranium-238 through to stable (non-radioactive) lead-206. Radon (radon-222) is a noble gas which decays as shown in Figure 1 through a series of short-lived radionuclides which, when they become attached to airborne dust particles, behave as solid particulates.

In terms of exposure, the most important radionuclides are the (short-lived) radon decay products which can deposit in the lungs when inhaled. To protect workers, clean ventilation air is provided to mine workplaces to remove the radon and short-lived radon decay products from the workplaces and out of the mine.

Above-ground emissions of particulates from both of these sources, radon decay products and uranium ore dust, are discussed below.

*Particulates from Radon Decay Products*

The primary radionuclides that could theoretically be released from ore loading are radon and uranium (and its decay products). According to the U.S. EPA *Background Information Document - Standard for Radon-222 Emissions from Underground Uranium Mines* (EPA 520/1-85-010, 10 April 1985), based on studies at multiple uranium mines in the southwestern U.S., the radon emissions from surface facilities, including ore stockpiles, development rock piles, and ore loading, are so small in comparison to emissions from vents, (specifically, *"insignificant when compared with the overall uncertainty in estimated total emissions,")* that they can be ignored in estimations of total radon emissions from a mine site. That is, the contribution to airborne radon concentration from ore loading operations is immeasurably small. That is why the radon emission standards in 40 CFR Part 61 Subpart B are limited to radon emissions from mine vents.

The mine operator is required to model dispersion of vent emissions over each operating year to determine exposure and the resulting dose to exposed individuals in the area potentially resulting from radon emitted from the mine. Moreover, the mine must comply with the radon dose limit of 10 mrem/year above background, to any member of the public. Denison models the dose from radon vented from the mine using EPA's approved COMPLY-R model, a very conservative model which demonstrates that as a result of atmospheric dispersion, the radon concentration drops rapidly with increasing distance from the mine vents. Denison also performs air dispersion modeling with the EPA's approved regulatory model for air dispersion, AERMOD, which unlike COMPLY-R, takes into account effects of local topography and actual hour-by-hour meteorology, shows even more rapid decreases in concentration with increasing distances from the mine vents.

Mine dispersion modeling performed by SENES for Denison in support of reporting to the EPA concerning the dose from radon released from mine vents demonstrates that radon emitted even at high concentrations from an up-cast (exhausting) vent, disperses quickly when mixed with air. For example, even in the case of mine vents exhausting air containing radon concentrations greater than 1,000 pCi/L of radon, upon mixing with air, the resulting concentration of radon is reduced to less than 0.2 pCi/L within a few hundred meters away from the vent. These concentrations are below the average outdoor level of radon in the U.S. of about 0.4 pCi/L and within the range of natural variability (NCRP Report No. 160, 2009). It should also be noted that the mass concentration (weight per volume) of particulates produced as radon daughter products could be expected to be an infinitesimally tiny fraction of the mass of mine dust at the same distance.

The contours of annual radon concentrations from the La Sal Mine developed using the EPA's AERMOD model show that radon concentrations are less than 5% of the background within a distance of 5 km from the mine complex. This rapid decrease of radon from combined mine vents is illustrated in Figure 2. The concentration of radon decay products produced as radon travels downwind would also be a small fraction of background levels at this distance.

*Particulates from Uranium Ore Dust*

SENES has prepared conservative estimates of the emission rate of radioactive dust from the La Sal Mine vents. The estimates were based on measured particulate concentrations in air collected underground in the La Sal Mines. The known uranium ore grades at the Mine were then used to develop conservative estimates of uranium, radium and other radioactive constituents in ore dust[1]. As discussed below, the levels of these radioactive constituents in the air were estimated to result in doses of at most 0.1 mrem in a year and are estimated to be three

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[1] As is common in most uranium ores, at La Sal, the ore is in radioactive equilibrium which means that each of the radionuclides in the uranium-238 decay sequence are all present at the same activity as the uranium-238.

orders of magnitude (a factor of 1000) lower than the annual dose limit and a tiny fraction of the dose from natural background. Therefore, these concentrations are of no consequence.

The La Sal Mine Complex has both surface and underground sources of dust emissions. The surface sources are from the ore and development rock piles, while the underground sources are from mine vents which exhaust air from the underground mine.

The dust emission rate from each mine vent was calculated by multiplying the flow rate ($m^3/s$) by a dust concentration of 1 milligram per cubic meter (1 $mg/m^3$). The dust emission rate was then converted to a uranium dust emission rate using a uranium content of 0.1% (i.e., 1/1,000 of the dust concentration). The 0.1% value was based on the assumptions that the dust is 2/3 ore and 1/3 development rock, and that the ore in dust is present at the average ore grade of 0.2%. The dust emission factor of 1 $mg/m^3$ is conservative as actual dust concentrations are lower[2] and likely overstates actual dust emissions, but was used in the calculations to be consistent with National Institute for Occupational Safety and Health (NIOSH) recommendations that worker exposure to coal dust be limited to 1 $mg/m^3$ of dust over a 40-hour work week. The resulting total uranium dust emission rate from the underground mine was estimated to be 0.454 g/s. The estimated dust emissions from the ore and development rock piles were taken from an air emissions report prepared for Denison (Redhorse 2010). The total estimated dust from the ore and development rock piles was 0.112 g/s. (This rate of emission would not be visible to the human eye).

The AERMOD results were then used to assess the dust concentrations at 10 receptor locations near the mine. The receptor locations consist of residences and non-residential locations, specifically the elementary school, church, post office, maintenance shed and livestock area. The estimated annual ore/development rock dust ($PM_{10}$, particulate matter of 10 micron ($10^{-6}$ m) size or less, which is considered inhalable) and uranium dust predicted concentrations from surface (ore and development rock piles) and underground sources at each receptor location are presented in Table 1.

Figure 3 shows the contours of annual dust concentration ($PM_{10}$) from the La Sal Mine Complex.

[2] Actual measurement data for silica dust concentrations on personal samples worn by workers in the La Sal Mine Complex provided by Denison averaged 200 to 300 $\mu g/m^3$. To provide a degree of conservatism, a mine exhaust air concentration of 1,000 $\mu g/m^3$ was assumed.

**Table 1**
**Annual $PM_{10}$ and Uranium Predicted Concentration**

| Receptor | Annual Concentrations (µg/m$^3$) $PM_{10}$ | Annual Concentrations (µg/m$^3$) Uranium |
|---|---|---|
| Residence #1 | 1.30E-01 | 1.30E-04 |
| Residence #2 | 5.99E-02 | 5.99E-05 |
| Residence #3 | 3.89E-02 | 3.89E-05 |
| La Sal Livestock | 1.96E-01 | 1.96E-04 |
| Catholic Church | 2.13E-01 | 2.13E-04 |
| Store/Post Office | 1.98E-01 | 1.98E-04 |
| Road Maintenance Shed | 2.87E-01 | 2.87E-04 |
| Elementary School | 2.08E-01 | 2.08E-04 |
| Residence #4 | 2.23E-01 | 2.23E-04 |
| Residence #5 | 1.42E-01 | 1.42E-04 |

The inhalation exposure pathway is the dominant exposure pathway for airborne dust. For each receptor, the inhalation dose used in the calculations was estimated for an adult receptor using the most recent Dose Coefficients (DCs) taken from the International Commission on Radiological Protection 72 (ICRP 1996) for the least soluble form (i.e., the form resulting in the highest dose). These DCs are reasonable because uranium ores are relatively insoluble. The DCs used in the calculations included the uranium-238 chain with its decay products in equilibrium.

The dose due to inhalation of airborne uranium (including the dose from all of the radionuclides in the uranium-238 decay chain) at each receptor location is presented in Table 2. The calculations assume continuous occupancy (365 days per year) at each location, which is very conservative, that is, it overstates the occupancy rate and exposure. The predicted doses are extremely small, with the maximum being less than 1/1,000th of the dose from natural background radiation. Actual inhalation doses using less conservative assumptions would be even lower.

**Table 2**
**Uranium Air Concentrations and Inhalation Dose**

| | Annual Concentrations ($\mu g/m^3$) | |
|---|---|---|
| Receptor | Uranium | Annual Dose (mrem/y) |
| Residence #1 | 1.30E-04 | 0.045 |
| Residence #2 | 5.99E-05 | 0.021 |
| Residence #3 | 3.89E-05 | 0.014 |
| La Sal Livestock | 1.96E-04 | 0.068 |
| Catholic Church | 2.13E-04 | 0.074 |
| Store/Post Office | 1.98E-04 | 0.069 |
| Road Maintenance Shed | 2.87E-04 | 0.10 |
| Elementary School | 2.08E-04 | 0.073 |
| Residence #4 | 2.23E-04 | 0.078 |
| Residence #5 | 1.42E-04 | 0.050 |

Note: A rem or millirem (mrem = one thousandth of a rem) are units of radiation dose. For perspective on the magnitude of the tabulated dose rates, the average dose in the United States from natural background radiation is 311 mrem/y (NCRP Report No. 160, 2009). The range (2.5 to 97.5 percentiles) in U.S. background doses is from less than 100 mrem/y to more than 1200 mrem/y.

1.2 *What are the potential hazards related to air emissions from the mine including dust and other emissions from the operation (e.g. diesel fumes, silica, arsenic, hazardous metals and metalloids, radon gas and its short-lived, highly radioactive decay products, uranium, and other uranium progeny).*

Hazards related to non-radioactive dust, diesel fumes, silica, arsenic, hazardous metals and metalloids were addressed by others. Potential effects from radon, uranium and their decay products are addressed below.

Radon and Radon Decay Products

As noted above, the dose from radon released from mine exhausts must be below 10 mrem per year to any member of the public. Denison performs modeling and reports to the EPA on the modeling to demonstrate that the mine is in compliance with the annual radon dose limit of 10 mrem per year. AERMOD modeling was performed to estimate atmospheric dispersion of the radon emissions from mine exhausts (for the calendar year of 2010) at the La Sal Mine Complex[3]. The estimated annual radon dose at each of the 10 receptor locations is shown in Table 3.

[3] For the modeling, one full year (April 2010 to March 2011) of hourly wind rose and temperature data from the Harm's Way meteorological station were combined with other basic AERMOD data and upper air data from the Grand Junction station.

**Table 3**
**Annual Radon Dose**

| Receptor | Dose (mrem/y) [a,b] |
|---|---|
| Residence #1 | 7.5(2.6) |
| Residence #2 | 4.4 |
| Residence #3 | 2.6 |
| La Sal Livestock | 8.4 |
| Catholic Church | 7.5 |
| Store/Post Office | 8.3 |
| Road Maintenance Shed | 8.1(1.9) |
| Elementary School | 8.6 |
| Residence #4 | 8.1 |
| Residence #5 | 4.3 |

Source: SENES (2011).
Notes: a) Harms Way meteorology (April 2010-March 2011)
b) (Values in brackets) adjusted for occupancy.
Residence R1 has partial occupancy during the year (from April 1 to October 31). R7 is an occupational setting with doses received for an estimated 2,000 hours each year

It can be seen from Table 3 that the modeled doses to all receptors assuming full-time occupancy are lower than the EPA's (40 CFR 61.22) 10 mrem/y standard for radon emissions from an underground uranium mine. When actual occupancies are considered at Receptor 1 and the Road Maintenance Shed, the likely actual exposures are much lower. For context, these incremental radon exposures are a small fraction of the dose from natural background, that is, the average dose from radon in the U.S. is 212 mrem/y (NCRP Report No. 160, 2009).

Uranium and Uranium Progeny (Daughter Products)

The effect from uranium and uranium daughter products was discussed in the response to Comment 1.1, above.

*1.3 What potential long-term effects to air quality could be caused by air emissions from the mine?*

The La Sal Mines are expected to have little or no long-term effect on air quality. As discussed in the response to other comments, above, the primary air emissions from the Mine are radon from the vents and particulates from above-ground facilities.

Radon is a short-lived radionuclide, with a half-life of 3.8 days. The daughter products of its decay are primarily isotopes of bismuth, lead and polonium which are not gases but are formed as charged atoms which attach to particles in the air and are removed from the atmosphere by deposition onto soil and surface during transport.

SENES has estimated that, based on the dispersion models for the La Sal Mine Complex vents, the incremental contributions of radioactive dust or radon from the mine decrease rapidly with increasing distance from the mine opening and surface installations, and in any event, are extremely small, well within the variability of natural background and of no consequence.

*1.4 What potential regional effects to air quality could be caused by air emissions from the mine?*

The regional effects on air quality have been addressed by others.

The La Sal Complex Mines operation's primary radiological effect on air quality would result from emissions from Mine vents. Mine Dispersion modeling performed by SENES demonstrates that radon, emitted even at high concentration from an up-cast (exhausting) vent, disperses quickly when mixed with air (see Figure 2). For example, as previously noted, radon exhausting from the vent (at more than 1000 pCi/L) is rapidly diluted upon mixing with air, and is estimated to be less than 0.2 pCi/L within several hundred meters from the vent. Also as previously noted, even at such close distances from a mine vent, such levels are well below the average outdoor level of radon in the U.S. of about 0.4 pCi/L and within natural variability (NCRP Report No. 160, 2009).

The La Sal Mine Complex is required to model dispersion of vent emissions over each operating year to determine exposure and resulting dose of radon to exposed individuals in the area. Air dispersion modeling using EPA accepted models demonstrates that, as a result of atmospheric dispersion, radon activity concentration drops to negligible concentrations within a short distance from the mine exhausts. In any event, the incremental levels are very small, and are well within background variability even close to the mine vents and even smaller with increasing distance. They are negligible contributors to regional air quality as for example, illustrated in Figure 4.

An isopleth map (an area model showing lines of equal radon concentrations at various distances from the operating vents, see Figure 4) developed by SENES compared concentrations of radon from the current operating and venting scenario to natural background radon concentrations measured at multiple locations in the La Sal Mine area and regional environment. The isopleth map indicated that the contribution of radon from mine vent emissions to the regional air quickly becomes indistinguishable from background concentrations of radon within a few hundred yards to a mile from the Mine site.

In addition, the isopleths indicate that the contribution of radon from the La Sal Mine Complex vent emissions to regional air (and therefore the effect of the La Sal emissions) do not overlap the areas of effect from other mines and operations in the area. Attachment B describes other current or reasonably foreseeable future uranium and non-uranium operations in the region surrounding the La Sal Mine Complex. The other known or foreseeable operations are too far distant from the La Sal operation for their respective potential areas of effect to overlap the area of potential effect from the La Sal Mine Complex. That is, as discussed in Attachment B, there will be no cumulative effect to air quality from the La Sal Mine Complex emissions when added to the emissions from other current and reasonably foreseeable future actions.

*1.5 Will ore loading operations at the mines cause a significant release of radionuclides?*

The primary radionuclides that could theoretically be released from ore loading are radon and uranium (and its decay products). According to the U.S. EPA *Background Information Document - Standard for Radon-222 Emissions from Underground Uranium Mines* (EPA 520/1-85-010, 10 April 1985), based on studies at multiple uranium mines in the southwestern U.S., the radon emissions from surface facilities, including ore stockpiles, development rock piles, and ore loading, are so small in comparison to emissions from vents, (specifically, *"insignificant when compared with the overall uncertainty in estimated total emissions,")* that they can be ignored in estimations of total radon emissions from a mine site. That is, the contribution to airborne radon concentration from ore loading operations is immeasurably small. That is why the radon emission standards in 40 CFR Part 61 Subpart B are limited to radon emissions from mine vents.

The other potential contribution to airborne radionuclide levels would be from uranium content of dusts generated in ore loading and transport. Based on site-specific data from the La Sal Mines, as prepared for the La Sal Mines State of Utah Air Order, the anticipated $PM_{10}$ emissions from all surface operations are estimated to be 0.12 g/s. Using an overly conservative assumption that all surface dusts contain the same uranium content as dust emissions from ores, and adding dust emissions from underground, also conservatively estimated, results in a maximum uranium $PM_{10}$ concentration of 2.87E-04 $\mu g/m^3$, which is negligibly low. In actuality, the uranium levels in airborne dust would be lower, since a portion of $PM_{10}$ at the site would be from development rock, road surface dusts, and ambient dusts that are of far lower uranium content than ores.

Based on the above considerations, ore loading operations will cause a negligible release of radionuclides.

## 2.0 RADIOLOGICAL ISSUES

*2.1 Are hazardous levels of radon gas, radioactive particles, and radioactivity released from rock piles during operation?*

Radon Gas

As noted in response 1.5, the contribution to airborne radon gas concentration from ore piles or development rock piles is immeasurably small relative to radon from mine vents and is therefore not present at hazardous levels.

Radioactive particles, including uranium dust and particulate daughter products of radon, from surface piles and dusts are considered to be low at the La Sal Mines due to the low grade of the ore. Based on calculations performed for the Mines' Utah Air Approval Order, particulate emissions are estimated to be low, with a maximum of 11.9 tons per year. This classifies the La Sal Mines as a minor source of particulate emissions under UDEQ permitting regulations. Particulate concentrations will be below the National Ambient Air Quality Standards at all areas outside the site perimeter. As a result, any hazard from particulates are negligible beyond this distance.

Moreover, ore piles, development rock piles and loading operations occur in controlled areas of the site with no public access. During operations, the public has no access to on-site piles or to dust generating equipment or activities. After cessation of operation, ore will be removed from the site, development rock will be returned to the mine or above-ground piles covered in accordance with the reclamation plan, and dust generating activities will cease. As a result, any potential health risks will drop accordingly.

Radioactive Particulates

As estimated by air emissions modeling for the La Sal Air Approval Order, particulate emissions from the vents can be assumed to be negligible compared to those from surface facilities and activities. Levels of uranium, radium and other radionuclides in air particulates from surface piles and dusts are low at the La Sal Mines due to the low grade of the ore. Based on calculations outlined above, particulate emissions are estimated to decrease rapidly with increasing distance with a maximum uranium $PM_{10}$ concentration of 2.87E-04 $\mu g/m^3$ (Table 2) which is negligibly low. In actuality, the uranium levels in airborne dust would be lower, since a portion of $PM_{10}$ at the site would be from waste rock, road surface dusts, and ambient dusts that are of far lower uranium content than ores.

Other Radiological Issues - External Gamma Radiation

The ore recovered from La Sal Mines operations has a relatively low uranium concentration. Correspondingly, the gamma radiation associated with these ores is low, and based on ongoing surveys and exposure determinations, does not pose a human health hazard to mine workers. Gamma radiation exposure levels depend largely on the uranium concentration in the ores being recovered, and at the La Sal Mines, the concentration is low and typically ranges between 0.05% and 0.25% $U_3O_8$.

In April 2011, Denison measured external gamma radiation measurements at the Pandora, La Sal, Snowball and Beaver Mine Sites. These measurements show that the external gamma radiation fields at the La Sal Mine are associated with ore piles temporarily stored on the surface and waste rock piles drop to near background levels within about ¼ mile. Waste rock piles, which have substantially lower uranium concentration than both the average ore grade being mined and the grade in temporary ore stockpiles, will correspondingly yield even lower gamma readings than ore-bearing material. Access to active mine areas is restricted, limiting general access by the public.

*2.2 Does mining at the La Sal Mine Complex increase cancer risk for workers or La Sal residents?*

2.2.1 Mine Workers

The La Sal Mine complex is operated in compliance with the requirements established by the Mine Safety and Health Administration ("MSHA"), which establishes standards and inspects operational practices to ensure mine worker safety. There are no operational practices proposed in the Plan of Operations Amendment that would impact the compliance of the La Sal Mine Complex with applicable MSHA requirements.

MSHA has determined (30 CFR 57.5037 through 57.5047) that for underground mine workers the primary potential health risks result from inhalation of radon gas and gamma radiation exposure from uranium decay. Denison is required to ensure that La Sal Mine workers do not incur exposures, measured in working levels months (WLM) that exceed prescribed doses for radon. Denison must maintain an annual cumulative radon exposure to within 4 WLM (30 CFR 57.5038). The prescribed exposure limits have been established to be protective for health effects, including cancer. MSHA requires that Denison measure and record radon levels underground, calculate doses to workers, and modify working conditions as required to meet the prescribed exposure limits.

In mines like the La Sal Mine Complex, which recover relatively low-grade uranium ores, gamma radiation is far less of a concern than in mines which recover higher grade ores. MSHA has established that annual individual exposure shall not exceed 5 rems for underground mine worker exposure to gamma radiation. As prescribed in 30 CFR 57.5047, annual gamma surveys are required to be conducted to determine the gamma radiation dose in all areas of the underground and surface workings where radioactive ores are present.

MSHA establishes maximum acceptable levels for diesel particulates and silica dust in underground mines. Similar to radon, the prescribed maximum levels of particulates were determined to be protective for health effects (such as black lung and silicosis) and cancer. MSHA considers that the maximum allowable levels and the controls for diesel particulates and silica are sufficient to also be protective from potential effects of radioactive particulates.

2.2.2 La Sal Residents

*Radon and Cancer Risk*

The public is protected from potential health effects from radon by the *Clean Air Act* National Emissions Standards for Hazardous Air Pollutants ("NESHAPs") which sets standards for the maximum allowable dose of radon to an individual from regulated emissions sources. In the United States, the average annual dose from natural background (including radon) is approximately 300 mrem per year (likely a bit higher in the Colorado Plateau area). Thus, the NESHAPs standard for radon, which allows a maximum dose of 10 mrem/y to any member of the public, is no more than about 1/30 of the dose that an individual would receive from natural background radiation. This dose of 10 mrem/y is the same dose an individual would receive on two round trip airplane flights from California to New York. Therefore, there will be no exposure or dose of any consequence, nor any measureable increase in cancer risk from radon or its particulate decay products, to any resident individual or passerby.

*Particulates and Cancer Risk*

The public will likewise not incur increased health risk from radionuclides in other air particulate emissions. The La Sal Mines Complex recovers relatively low grades of ore, generally from 0.05 to 0.25 percent $U_3O_8$. The radionuclide content of development rock, which by definition contains uranium grades lower than economically minable ore, will be even less than the radionuclide content of the ore.

Exposure of residents and the public to particulates, and the associated health risks, are expected to be immeasurably low and indistinguishable from natural background. As discussed in the response to Comment 1.1, above, very conservative estimates of particulate emissions from vents result in a dose to receptors of less than 0.1 mrem/y or a small fraction of the dose from natural background, that is, it is indistinguishable from natural background. Levels of uranium, potentially related to cancer risk, in air particulates from surface piles and dusts are considered to be low at the La Sal Mine Complex due to low grade of the ore. Based on calculations performed for the Mines' Utah Air Approval Order, particulate emissions are estimated to be low, with a maximum of 11.9 tons per year, which classifies the La Sal Mines as a minor source of particulate emissions under UDEQ permitting regulations. Particulate concentrations will be below the National Ambient Air Quality Standards at all areas outside the site perimeter. As a result, any hazard from particulates is insignificant beyond this distance.

Moreover, as previously indicated, ore piles, development rock piles and loading operations occur in controlled areas of the site with limited public access. During operations, the public has no access to ore piles or to dust generating equipment or activities. After cessation of operation, ore will be removed from the site, development rock will be returned to the mine or above ground piles covered in accordance with the reclamation plan, and dust generating activities will cease, and, as a result, any potential health risk will drop accordingly.

*2.3 Do uranium, radon, radium, or other radionuclides bio-accumulate in vegetation?*

While some radionuclides are known to accumulate in vegetation through uptake from soil or water in root systems, bioaccumulation requires the deposition of sufficient amounts of radionuclides in vegetated soils to result in any measurable concentration in plant tissues. Deposition in the La Sal Mine Complex area is expected to be minimal for the following reasons.

As discussed in the response to comment 2.1, above, particulate modeling prepared for the Mine Complex Utah Air Approval Order demonstrates that particulate dispersion from development rock and ore piles becomes immeasurable beyond a few hundred feet to a mile from the Mines. Dispersion modeling performed for radon emissions from vent sources, and therefore the dispersion of radon daughter products, shows that the radon (and radon decay products released from mine vents) becomes indistinguishable from background beyond a few hundred yards to a mile from the Mine site. As previously noted and illustrated in Figures 1 and 2, the levels of radon and dust arising from activities at the Mine Complex decrease rapidly with increasing distance and even close to the Mine Complex present only a very small increase to the radiation dose from natural background. These numbers are well within natural variation in background and thus, are negligible with respect to the deposition of radionuclides; therefore, uptake and bioaccumulation of deposited radionuclides in the local environment are of no consequence. To illustrate, SENES estimates that even after 40 years of operation at current rates, the total concentration of uranium accumulating in the upper soil horizon (5 cm) would be about 0.01 ppm close to the vent exhausts (and less elsewhere). This is a small fraction (less than 1%) of natural background levels in U.S soils which range from about 0.6 to 3 parts per million (NCRP Report No. 160, 2009). (One part per million is approximately equivalent to 2.6 quarts of water in an olympic-sized swimming pool). The theoretical increment to soil radioactivity from the Mine Complex would be very small compared to background and would not affect plants or animals.

*2.4 What are the effects of radon emissions and radon progeny on vegetation, soils, water and wildlife near the vent holes?*

Biota may be exposed externally to radiation in the environment and internally from radionuclides taken into the biota. For example, terrestrial organisms are exposed externally to radiation from the nearby soil, through uptake from the soil, and through uptake through food chains[4]. Various international and national authorities have developed approaches to assessing radiation doses to non-human biota and the potential effects of such exposures (including for example, UNSCEAR 2008, IAEA 1992 and the U.S. DOE 2002 among others).

The procedure for evaluating risks to non-human biota involves estimating dose rates and comparing the estimated dose rates to reference dose rates below which no effects are expected on populations of plants and animals. The recent evaluation by UNSCEAR (2008) concluded that chronic dose rates of 100 μGy/h (approximately 10,000 μR/h) to the most highly exposed biota are unlikely to have an effect on populations of terrestrial biota. In Section 2.3, it was noted that even after 40 years of operation at current rates, the total concentration of uranium accumulating in the upper soil horizon (5 cm) would be about 0.01 ppm close to the vent exhausts (and less elsewhere). This is a small fraction (less than 1%) of natural background levels in U.S soils which range from about 0.6 to 3 parts per million (NCRP 2009). Thus, the radiation dose to plants and animals living in the vicinity of the mine site would be indistinguishable from natural background levels. NCRP report No. 160 (2009) indicates the external gamma doses in the Colorado Plateau area are on the order of 0.05 to 0.08 μGy/h (i.e., 5 to 8 μR/h). The estimated dose rates around the La Sal Mine Complex from all sources of radiation combined are of the same order as background and are hence several orders of magnitude lower than the dose rate noted above of 10,000 μR/h which UNSCEAR has determined would have no effect on vegetation or animals.

*2.5 What are the risks associated with direct contact to radium, radon, and radon progeny during mine operation and after mine reclamation?*

<u>During Mine Operations</u>

*Radon and Progeny (Daughter Products) during Mine Operations*

Radon is a chemically inert gas. Direct "contact" with the gas poses no chemical health hazard. The primary risks associated with radon result from chronic exposure via inhalation. The risks of inhalation of radon and radon daughter products during mine operations were discussed in the response to Comment 1.1, above.

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[4] Chambers *et al.* 2008 provides a discussion of the approach to risk assessment for non-human biota.

*Radium during Mine operations*

Exposure to radium for workers or the public would result from exposure to particulate dust from underground workings or development rock and ore stockpiles. Protective measures for worker "direct contact" are described in the response to Comment 8.2, below. Because the La Sal Mine Complex has controlled access, during operations the public will have no opportunity for direct contact with vents and no access to the underground workings. Access to the development rock piles and ore stockpiles is limited. The only opportunity for ongoing exposure would be through inhalation of dusts. As discussed in the response to Comments 1.1 and 2.2, air particulate $PM_{10}$ levels from the site are minimal, as low as 11.9 tons per year, which classifies the La Sal Mines as a minor source of particulate emissions under UDEQ Permitting regulations. Radium forms a very tiny percentage of the mass of $PM_{10}$. As described previously in the response to the potential impacts of bioaccumulation (Section 2.3), even after 40 years of operation and deposition, the buildup of deposited radionuclides, including radium in equilibrium with Uranium-238, is very small, a fraction of natural background, including adjacent to exhausting vents. Therefore, exposure and associated health risks are expected to be negligibly small and indistinguishable from background.

<u>After Mine Reclamation</u>

*Radon and Daughter Products after Mine Reclamation*

Per the U.S. EPA Background Information Document - Standard for Radon-222 Emissions from Underground Uranium Mines (EPA 520/1-85-010, 10 April 1985) based on studies at multiple uranium mines in the southwestern U.S., in comparison to mine vents, the radon emissions from surface facilities, including ore stockpiles, development rock piles, and ore loading, are negligibly small in comparison to emissions from vents and can be ignored in estimations of total radon emissions from mine sites. As a result, the contribution to airborne radon gas concentrations from surface sources is immeasurably small relative to radon from mine vents and is therefore not present at hazardous levels.

*Radium after Mine Reclamation*

During reclamation and closure, any ore remaining on the surface would be shipped to the White Mesa Mill for processing, or replaced inside the mine workings. Therefore, there would be no opportunity for public exposure to the uranium contained in the ores and no post-reclamation risk from ore. Radium levels in development rock would be substantially lower than levels in the ore. After reclamation, development rock will be covered with inert material thereby virtually eliminating any potential for dispersion of radium above natural background levels and effectively reducing gamma levels to those of the cover materials.

2.6 *What are the risks associated with emission of radon from ore pads, ore stockpiles, vent hole areas, and drill cutting disposal areas?*

Ore Pads and Pre Stockpiles

Per the U.S. EPA *Background Information Document - Standard for Radon-222 Emissions from Underground Uranium Mines* (EPA 520/1-85-010, 10 April 1985) based on studies at multiple uranium mines in the southwestern U.S., in comparison to mine vents, the radon emissions from surface facilities, including ore stockpiles, development rock piles, and ore loading, are small in comparison to emissions from vents and can be ignored in estimations of total radon emissions from a mine site. As a result, the contribution to airborne radon gas concentration from ore piles or other surface sources is immeasurably small relative to radon from mine vents and is therefore not present at hazardous levels.

Vent Holes

The risk associated with vent holes are discussed in the response to comment 1.1, above.

Drill Cuttings

Drill cuttings are generated in two types of exploration areas at the La Sal Mine Complex, underground and above-ground explorations. All drill cuttings which are generated underground in the mine workings, are combined with, and handled as part of, development rock, which is managed in above-ground development rock piles. The risks from underground drill cuttings are accounted for in the assessment of risks from underground dust, underground radon, and above-ground development rock piles, which are discussed in the responses to Comments 1.1, 1.2, and 2.1, above.

Drilling from surface yields approximately 1 to 3 holes per day, or an average of 2 drill holes per day. Drill holes are approximately 5 to 6 inches in diameter. The upper portion of drill holes is non-mineralized rock, that is, contains no uranium. The ore zone in the La Sal Mines Complex averages approximately 3.5 feet thick. At these dimensions, drilling produces approximately 65 to 95 lbs of mineralized cuttings per day for each hole. In comparison, the mine produces and hauls to the surface an average of approximately 536,000 lbs per day of ore. The risks from surface ore piles (dusts, radon and gamma), as discussed in the response to Comment 1.5, above, are negligible both during and after operations.

The potential risks from drill cuttings are negligible for two reasons. First, the mass of drill cuttings is small. Second, drill cuttings are not left on the surface. All cuttings are placed in excavated drill pits and covered with inert surface soils after completion of drilling and closure of the pits. Pits are closed and covered within days of excavation, resulting in no opportunity for public contact with the pit contents. Surface gamma surveys are conducted after closure of drill sites as a further step to ensure that no uranium bearing material remains on surface.

2.7 *What is the appropriate reclamation performance criterion for emission of radiation from reclaimed areas?*

No federal or state radiological standards currently exist for reclamation of development rock areas at uranium mine sites. In fact, under Section 6.2 of the Atomic Energy Act (42 U.S.C. 2092), and as set out in 10 CFR 40.13(b), the Nuclear Regulatory Commission has specifically excluded natural ores from regulation under the Atomic Energy Act.

However, despite the fact that there is no current state or federal standards for reclamation of development rock areas at uranium mine sites, Denison has voluntarily agreed to a standard for its mines in Utah. Under this standard, mine-disturbed areas would be reclaimed such that the potential dose to a member of the public, assumed to be a person camping on or near a development rock pile for 14 days, is less than 100 mrem/year above background. This 100 mrem/year standard is supported technically by recommendations from the National Council on Radiation Protection and Measurements (NRCP) [See NRCP Statement 10, Recent Applications of the NCRP Public Dose Limit Recommendation for Ionizing Radiation, (NCRP, 2004), and NCRP's Report No. 116, Limitation of Exposure to Ionizing Radiation (NCRP, 1993)]. It is also a standard that is consistent with the numerical public dose protection standard set by the Nuclear Regulatory Commission (NRC) for uranium milling facilities as set forth at 10 CFR Part 20, Subpart D § 20.1301 - Dose limits for individual members of the public, which provides in part:

(1) The total effective dose equivalent to individual members of the public from the licensed operation does not exceed 0.1 rem [100 mrem] in a year, exclusive of the dose contributions from background radiation, from any medical administration the individual has received, from exposure to individuals administered radioactive material and released under § 35.75, from voluntary participation in medical research programs, and from the licensee's disposal of radioactive material into sanitary sewerage in accordance with § 20.2003.

[56 FR 23398, May 21, 1991, as amended at 60 FR 48625, Sept. 20, 1995; 62 FR 4133, Jan. 29, 1997; 67 FR 20370, Apr. 24, 2002; 67 FR 62872, Oct. 9, 2002].

Utah has adopted the same standard for uranium mills in UAC R313-15-301.

## 3.0 RADON

*3.1 How are vent shafts used, intake or vent and when and why are they closed and not used. Explain the basis for assumptions.*

Mine Ventilation

Vents at the La Sal Mine Complex include vents which are forced up-cast (blow air out of the mine), forced downcast (blow air into the mine) and vents with no fans, which ventilate air in or out of the mine in response to the air movement pattern generated by other vents. Vents must meet two simultaneous objectives: specifically to manage underground conditions to meet MSHA requirements applicable for the safety of workers, while at the same time minimizing impacts to environmental receptors – human and ecological.

Mine ventilation to meet the needs of miner safety is dynamic and changes constantly depending on underground factors including:

- Where mining is occurring underground;
- The grade of the mined rock and ore;
- The rate of mining.

Effects of mine ventilation on the environment are also dynamic and depend on the above factors as well as:

- Local meteorology (especially wind speed);
- Location (distance and elevation) of vents and receptors.

The mine operator is continually evaluating methods to reduce radon emissions. Emissions reduction measures may include conversion of certain up-cast vents to downcast vents, capping of certain vents in mined out sections of the mine, and bulk-heading (sealing off) sections of the mine where mining is completed but may resume in the future.

Assumptions

For the purposes of assessing impacts (exposure) to the receptors in the surrounding community, from ongoing operations, all parameters used in models and calculations are measured data, and no assumptions have to be made. For vents with known flow directions (forced up or down by fans) flow directions are confirmed and flow rates are measured and recorded at least monthly. For vents without fans or with variation in flow direction, flow directions are confirmed and flow rates generally are measured and recorded several times per month. Radon concentrations are measured by track etch canisters, and an ongoing study is evaluating the effectiveness of measuring radon daily with scintillometric detectors (which convert the incident radiation energy into light energy in a photomultiplier tube).

For estimation of impacts from future activities, Denison has used one of two methods. Where data for the same activity or conditions exists from previous operations at the La Sal Mines Complex or other similar mines, results are extrapolated or adapted for the proposed future scenario. Alternatively, effects are estimated from conservative assumptions where past operations data is not available or applicable.

*3.2 How does the apparent lack of local meteorological data affect the analyses of radon risks to the community of La Sal and surrounding areas?*

There is no lack of local meteorological data for the La Sal Mine Complex area. At the time of publication of the 2009 NESHAPs Annual Report for the La Sal Mines Complex, Denison was aware of only one full set of meteorological data suitable for providing inputs for radon dispersion modeling. Dispersion modeling for that report used the EPA data set for Grand Junction Airport, CO (for the period 1987-1991), 85 km northwest of the site. The Grand Junction data set was selected at that time for the following reasons:

- It provided the most complete data set (most parameters);
- The data is reliable;
- At least 5 full years of continuous data are available;
- The data is consistent with the wind direction data from the meteorological station at Lisbon Valley, which is closer to the site.

Since the publication of the 2009 NESHAPs Report, which was submitted in March 2010, the U.S. Department of Agriculture has installed the Harm's Way Meteorological Station in the town of La Sal, Utah, which is located near the La Sal Mines area. A full year of data from that station became available in May 2011 and is available for use in calculating the estimated dose for 2010 and subsequent years. The Harm's Way data provides local wind speed and direction, which, together with certain upper air data from the Grand Junction Meteorological Station, will be adequate for modeling at the Mine site.

*3.3 How is dispersion of radon affected by seasonal weather changes such as cold weather and temperature inversions - what effect does this have on potential risks to the La Sal community and other receptors?*

Daily and seasonal weather changes create variations in dispersion of radon emissions. However, the short-term variations in dispersion are reflected the calculated annual average concentrations and in the dose calculations. Consistent with the EPA's NESHAPs requirements, the maximum allowable dose of 10 mrem is a maximum allowable *annual* dose. The dose to any receptor is calculated, and the maximum dose compared to the regulatory limit of 10 mrem *for an entire year*. That is, the total exposure to any individual from the La Sal Mine Complex vents may not exceed the 10 mrem level, for an entire year. Denison's radon emissions reports provide estimates of radon emissions and associated doses for a 12 month period, including historic results for all months of the year, and therefore reflect daily, monthly and seasonal influences. This approach accounts not only for month-to-month changes in radon emissions, but also for the month-to-month variations in atmospheric dispersion.

*3.4 How will radon risks and potential effects to the La Sal community and other potential receptors vary during the three mine phases and during potential mine shutdown?*

During all phases of development and ore mining, it is important to provide miners with clean fresh air. This air is exhausted from the mine via mine ventilation exhausts (vents). The highest radon emissions are expected to arise from actual ore mining with lower release arising from development waste rock.

According to the U.S. EPA *Background Information Document - Standard for Radon-222 Emissions from Underground Uranium Mines* (EPA 520/1-85-010, 10 April 1985) based on studies at multiple uranium mines in the southwestern U.S., in comparison to mine vents, the radon emissions from surface facilities, including ore stockpiles, development rock piles, and ore loading, are small in comparison to emissions from vents, and can be ignored in estimations of total radon emissions from a mine site. That is, the contribution to airborne radon gas concentration from ore piles or development rock piles is likely to be very small, and the primary potential source of radon is from vents. Thus, during mine operation, including development of new underground openings, the radon from mine vents is expected to be the largest source of mine related radon.

The Clean Air Act's Radon NESHAPs regulations require that Denison limit total radon emissions from all vents to limit the radon dose to less than 10 mrem per year to any member of the public. The radon dose level of 10 mrem per year has been determined by U.S. EPA to be protective of human health with no measurable increase in health risk. Denison is required to meet this standard at all times, regardless of which phase of operations the Mine is in. The NESHAPs standards continue to apply during temporary mine cessation so long as the Mine is being ventilated; however, under temporary mine cessation, the quantity of radon emissions is generally reduced considerably. As a result, the variation in later phases will generally result in a reduction of risk.

Following mine decommissioning, the ventilation holes will be backfilled or capped eliminating radon from ventilation holes, thus leading to reduction in radon releases, for practical purposes to near background levels.

*3.5 What are the effects of radon and its progeny to firefighters who may need to fight a wild-land fire in the vicinity of the vent shafts?*

The mine dispersion modeling demonstrates that radon, emitted even at high concentration from an up-cast (exhausting) vent, disperses quickly when mixed with air. For example, as previously noted, radon exhausting from the vent (at more than 1000 pCi/L) is rapidly diluted upon mixing with air, and is estimated to be less than 0.2 pCi/L within several hundred meters from the vent. Thus, exposure to radon and its decay products from the vents would not pose a hazard to firefighters who work near the vent for short periods of time.

More importantly, the Mine has the ability to turn off, or downcast, a vent if a nearby fire requires firefighter access to areas near vents. Mine activities can be temporarily ceased or modified, venting patterns changed, or vent fans shut off, as required for protection or convenience for firefighters or other emergency response personnel, if necessary. Firefighters may also don Self-Contained Breathing Apparatus ("SCBAs") when entering areas with hazardous levels of airborne soot, smoke, other particulates, hazardous chemicals, combustion by-products, or reduced oxygen. The SCBA is more than adequate for full protection from radon decay products in breathing air. Nonetheless, the Mine is capable and willing to shut off specific vent flows as needed to accommodate firefighters even without use of breathing equipment.

*3.6 What are the effects of radon and its progeny to the community of La Sal and the surrounding areas?*

The effects of radon and its decay products to the community of La Sal were addressed in the response to the comments under item 3.4, above.

As discussed in those responses, neither radon nor its daughter products will be of sufficient concentration to exceed exposure limitations when dispersed any distance beyond the La Sal Mines Complex area; that is, there will be no effect to the surrounding areas because there will be no substantial air or water transport of constituents to those areas.

*3.7 What are the effects of radon and its progeny to the recreating public?*

The Clean Air Act's Radon NESHAPs regulations require that Denison limit total radon emissions from all vents from the mine to limit radon dose to less than 10 mrem per year to any member of the public. The radon dose level of 10 mrem per year has been determined by the U.S. EPA to be protective of human health. Compared to the natural background radon levels in the La Sal area, the dose from the allowable radon emissions are a small fraction of the dose from natural background radon levels.

The models used to determine radon doses from the La Sal Mine Complex's measured vent emissions of radon make the over-conservative assumption that exposed individuals are all residents, and are present 24 hours per day, 365 days per year (that is, 8760 hours per year). Relative to the recreating public, the above standard for full time residents is conservative. The recreating public are present from hours, to several days, to several weeks per year. Since the 10 mrem per year is protective of individuals who are assumed to be present full time 365 days per year, it is also protective of members of the recreating public who are present for far shorter periods of time.

*3.8 What are the effects of radon emissions and radon progeny on vegetation, soils, water, and wildlife near the vent holes?*

Vegetation and Wildlife

The primary source of potential radiation exposure near vent holes would be from radon and radon daughter products from vent emissions. As discussed above, various international and national authorities have developed approaches to assessing radiation doses to non-human biota addressing both direct radiation and the soil and food chain uptake pathways, and the potential effects of such exposures (including for example, UNSCEAR 2008, IAEA 1992 and the U.S. DOE 2002 amongst others).

The procedure for evaluating risks to non-human biota involves estimating dose rates to populations of plants and animals, and comparing the estimated dose rates to reference dose rates which are expected to have no effects on populations of plants and animals. As previously noted, a recent evaluation by UNSCEAR (2008) concluded that chronic dose rates of 100 μGy/h (to the most highly exposed biota) are unlikely to have an effect on populations of terrestrial biota. As discussed in the response to Comment 2.4, above, the radiation dose to plants and animals living in the vicinity of the mine site would be indistinguishable from natural background levels. NCRP report No. 160 (2009) indicates the external gamma doses in the Colorado Plateau area are on the order of 0.05 to 0.08 μGy/h (i.e., 5 to 8 μR/h). Measurements Denison's external gamma radiation survey conducted in April 2011 show the gamma radiation dose rates around the La Sal Mine Complex from all sources of radiation are of the same order as background and hence several orders of magnitude lower than the dose rates which UNSCEAR has determined would have no effect on vegetation or animals.

Deposition on Soil and Other Indirect Effects

As defined by BLM (2010), indirect effects or impacts "...are those caused by the action that occur later in time or farther removed in distance, but are still reasonably foreseeable." For the present case, these could include the deposition of ore dust off-site resulting in subsequent exposures via direct gamma radiation (ground shine) or via ingestion of produce. Such exposure pathways were modeled assuming a fixed dust concentration and long-term (40 years) dust deposition in order to maximize the amount of deposited dust and potential exposures via these indirect pathways. These results (presented in Attachment C) showed that the dominant exposure pathway, even after 40 years of operations, was inhalation and that build-up in soil was a negligible dose contributor as previously noted in response to comment 1.1.

Water

Even after 40 years of operation, the buildup of deposited radionuclides is very small, a fraction of natural background, even adjacent to a vent. Moreover, the uranium in its original form, that is the form in the ores and development rock, is quite insoluble, which is why it takes intensive chemical processing to remove the uranium from the ore at the White Mesa Mill. Thus, given the small amount of deposited uranium and its low solubility, there is no reason to expect any measurable transport to surface waters, or any radiological issues with surface water arising from deposition.

*3.9 Would installation of diffusers at various heights affect dispersion of radon and potential effects to the local community and other potential receptors?*

Diffusers are mechanical devices, often screens or grids, which are used to slow a fluid's velocity and enhance its mixing with another fluid at an outlet or discharge point. Installation of diffusers would not make any measureable change in the dispersion of radon or the effects to the La Sal area receptors, except at a few vents. The majority of the La Sal emission points (23 out of 30) are either:

- low flow up-cast vents, portals, or shafts without fans;
- low flow up-cast vents with fans; or
- vents, portals, or shafts which vary from up-cast to downcast at low flow rates.

Diffusers would provide no reduction in flow rate, and little or no additional mixing, for these emissions points. Diffusers may provide some additional localized change in dispersion (scattering or spreading of radon) at continuous forced up-cast vents. However, dispersion modeling based on data from several different meteorological stations, and combinations of data from these stations (SENES May 2011) indicates that existing natural dispersion is sufficient to reduce the radon concentrations from even the highest emitting vent to very low levels within a few hundred feet of the vent and to practically zero within a mile of the vent. Therefore, the installation of diffusers is not necessary and would be of little benefit.

As discussed above, the total radon dose from the La Sal Mine Complex vents to any member of the public is required by the provisions of the Clean Air Act Radon NESHAPs to be no more than 10 mrem per year, or less than about 1/30$^{th}$ of the dose from natural background radiation.

## 4.0 SOILS

*4.1 Are soils at the mine sites contaminated with metals, uranium, or uranium progeny?*

Development rock piles, ore piles, and soils in and around loading areas all have some very small levels of uranium, uranium daughter products and non-radioactive metals.

The quantity and effects of windborne dust carried offsite from rock piles, ore piles, and on-site soils is discussed in the responses to Comments 1.1, 1.2, and 2.1, above.

As discussed in the response to Comment 1.1, above, very conservative estimates of particulate emissions from vents result in a dose to receptors of less than 0.1 mrem/year or a small fraction of the dose from natural background, that is, indistinguishable from natural background. Levels of uranium, radium and other radionuclides in air particulates from surface piles and dusts are considered to be low at the La Sal Mine Complex due to the low grade of the ore. Based on calculations performed for the Mines' Utah Air Approval Order, particulate emissions are estimated to be low, with a maximum of 11.9 tons per year, which classifies the La Sal Mines as a minor source of particulate emissions under UDEQ permitting regulations. Particulate concentrations will be below the National Ambient Air Quality Standards at all areas outside the site perimeter. As a result, any hazard from particulates is insignificant beyond this distance.

## 5.0 UNNECESSARY OR UNDUE DEGRADATION

*5.1 Is Denison currently in compliance with environmental laws relating to air quality?*

The La Sal Mine Complex is regulated by a Utah Division of Air Quality Air Approval Order, and by the requirements of 40 CFR 61 Subpart B which regulates the emission of radon from the Mine.

Utah Air Approval Order

The La Sal Mine Complex currently operates under a Utah Division of Air Quality Air Quality Approval Order. Denison has submitted a Notice of Intent (NOI) application to UDEQ for approval to modify the permit to increase ore production and to add several small diesel generators for backup power if primary power is interrupted. As of the publication of this technical memorandum, the NOI application is still being processed by UDEQ.

40 CFR 261 Subpart B (Radon NESHAPs)

Under 40 CFR 61.22, emissions of radon-222 to the ambient air from an underground uranium mine shall not exceed those amounts that would cause any member of the public to receive, in any year, an effective dose equivalent ("dose") of 10 millirem per year (mrem/year). Further, 40 CFR 61.23(a) provides that compliance with that emission standard shall be determined and the effective dose equivalent calculated by the U.S. EPA computer code COMPLY-R or by the use of computer models that are equivalent to COMPLY-R, provided that the model has received prior approval from EPA headquarters.

During a conference call between Denison representatives and representatives of EPA head office, EPA Region 8 and the State of Utah Department of Environmental Quality, Division of Air Quality on February 23, 2010, Denison advised that it did not believe COMPLY-R was a suitable model to determine compliance with the emission standard in 40 CFR 61.22 at the La Sal Mine Complex, due to the complex site-specific features. Denison requested guidance as to how it should proceed to obtain prior approval for the use of the EPA-approved AERMOD model as a more sophisticated basis for demonstrating compliance with those standards. It was agreed that Denison would perform an analysis of the suitability of each of those models to the site specific features at the La Sal Mine Complex, including a comparison of emission results from each model, and prepare a report that would support an application by Denison for EPA approval of the use of AERMOD, rather than COMPLY-R.

SENES, retained by Denison to evaluate the models, concluded in a 2009 report (the "2009 SENES Report") that COMPLY-R is not a suitable model for calculating doses in the vicinity of the La Sal Mine Complex, due to the complex features associated with the La Sal Mine Complex, and that AERMOD will provide much more accurate estimates of such doses. SENES concluded that the COMPLY-R model is unduly conservative for the La Sal Mine Complex because it is not equipped to accurately deal with the multiple sources and receptors spread over a broad area, the complex terrain and elevations and the variable emission rates associated with the La Sal Mine Complex. SENES concluded that AERMOD will provide more accurate model predictions of the radon concentrations and doses, because it is equipped to handle multiple sources and receptors, complex terrain and variable emission rates. Denison submitted its request to EPA headquarters for approval to use AERMOD instead of COMPLY-R on March 30, 2010, along with its submittal of the 2009 Annual Report.

Denison used Method A-7 to analyze radon-222 and used commercially-available, alpha track radon-222 detectors to continuously collect radon-222 emissions on a monthly basis for January through December of 2009, as per previous reports and industry practice. On April 26, 2010 Denison submitted to EPA headquarters an application to use Method A-7 at the Mine, and is currently working with EPA to evaluate radon-222 measurement methods.

The dose results for AERMOD, calculated by SENES, show 2010 potential doses ranging from 2.6 to 8.6 mrem/y for the receptors in the vicinity of the La Sal Mine Complex (Table 3). Those doses are less than the 10 mrem/y standard set out in 40 CFR 61.22, and are considered by SENES to be the best estimate of doses in the vicinity of the Mine for 2010 radon emissions.

COMPLY-R was then run in a number of different ways on the 2009 radon emission data, from the simple base case to increasingly more complex ways in an attempt to take into consideration the multiple sources and receptors, complex terrain and variable emission rates at the La Sal Mine Complex. All of those runs resulted in one or more receptors exceeding the 10 mrem/y standard, based on 2009 radon emissions data. However, SENES concluded that in using COMPLY-R, an accurate dose estimate incorporating the monthly variation in emissions and elevation changes at the La Sal Mine Complex was not possible. SENES further concluded that the investigation into monthly emissions and sensitivity of elevations in site terrain suggests that COMPLY-R is overly conservative for the Mine sites, and that, although COMPLY-R may be appropriate for simpler cases (e.g. single sources, distant receptors, constant emissions through the year), it should only be considered as a screening model for a complex site such as the La Sal Mine Complex. SENES therefore recommended the use of AERMOD to address the site-specific conditions at the La Sal Mine Complex.

On July 21, 2010, EPA responded to Denison's March 30, 2010 application to use AERMOD at the La Sal Mine Complex for purposes of compliance calculations under 40 CFR 61.23 and Denison's April 26, 2010 application to use Method A-7 at the Mine. EPA concluded that:

i) It is unable to approve the use of Method A-7 at the Mine until Denison collects data from the Mine vents using both Methods A-6 and A-7 at the same time; and
ii) Since EPA has concerns about the accuracy of the monitoring data collected using Method A-7, which was collected and subsequently used for the direct comparison of the two computer models, EPA cannot approve Denison's request to use AERMOD until Denison has demonstrated the accuracy of the input data.

On August 17, 2010 EPA issued a Notice of Violation (the "NOV") relating to Denison's compliance with the standards in 40 CFR Subpart B for 2009. In the NOV, EPA noted that on July 21, 2010 it had denied Denison's March 30, 2010 request to use AERMOD for compliance calculations at the Mine and Denison's April 26, 2010 request to use Method A-7 at the Mine, and cited the following alleged violations:

i) Emissions of radon-222 from the Mine during 2009 exceeded the emission standards for six receptors, in violation of 40 CFR 61.22 and Section 112 of the Clean Air Act (the "CAA"), using COMPLY-R;
ii) Denison has not submitted monthly reports following the emissions exceedances of radon-222 for the year 2009, in violation of 40 CFR 61.24(b) and Section 112 of the CAA;
iii) Emissions of radon-222 from Vent 1350, Pandora 3, Pandora 7, and Pandora 12 have not been continuously monitored, in violation of 40 CFR 61.23(a) and Method 115, and Section 112 of the CAA; and
iv) Method A-7 has been used to analyze radon-222 in lieu of Method A-6 at the Mine, without prior approval from EPA, in violation of 40 CFR 61.23(a) and Method 115 and Section 112 of the CAA.

As a result of the NOV, Denison submitted the first monthly report under 40 CFR 61.23(b) for the month of September 2010, and each month thereafter, which meet the requirements of 40 CFR 61.24(b) and demonstrate completeness of the continuous monitoring in compliance with 40 CFR 61.23(a).

On December 13, 2010, Denison submitted a proposed approach for implementing a site-specific comparison of Method A-6 and Method A-7 that will provide test results acceptable to EPA, to determine if continuous scintillometry (Method A-6) is feasible and reliable in the conditions at the Mine. The side-by-side test is currently underway.

Denison has also requested EPA to evaluate the use of AERMOD at the site while this comparison study is taking place, on the basis that it is still possible to undertake a meaningful comparison of AERMOD and COMPLY-R so long as the same input data is used for each model.

As a result of those applications and ongoing discussions between EPA and Denison, EPA has decided not to pursue the two alleged violations relating to the manner of monitoring for radon at the site and the alleged exceedances of the emission standards. The remaining two violations, which relate to gaps in data collection and reporting, have been settled through the execution and delivery of a consolidated Complaint and Consent Agreement and the payment by Denison of a stipulated penalty.

## 6.0 WATER

### *6.1 Is there potential for radon to enter the public water supply?*

There is no is public/municipal water supply in the La Sal area. All drinking water is supplied by individual private wells. There is little or no potential for radon to enter the private water supply of any well in the area for the following reasons.

<u>Access to groundwater from mine workings:</u>
The proposed areas of the mine workings addressed by the POA are dry areas, that is, groundwater has not yet been encountered in the mine. Uranium bearing ore zones are not in contact with groundwater; hence a mechanism for solubilization and transport of radon into groundwater is not available within the mine.

<u>Access to groundwater from vents:</u>
Radon is a gaseous by-product of uranium decay. Its daughter products are charged particulates (solid particles). As discussed above, the transport of radon and its daughters in the environment would be primarily via emission and atmospheric dispersion from mine vents. To have any

effect on the private drinking water wells in the area, radon in vent emissions would have to be transported from the mine vents, deposited on near surface soils, re-solubilized in the near surface and encounter a hydraulic head sufficient to drive solubilized shallow contaminants into the aquifer that supplies the area's drinking water wells.

The majority of the wells used in the area appear to be completed in the D aquifer and in alluvial aquifers located south and west of the La Sal Mines Complex near the town of La Sal. The D aquifer is separated from the areas of mining by the Brush Basin member of the Morrison Formation, which is a low-permeability confining unit.

The well intake depths range from 0 to 460 ft below the surface, and the static water levels range from 0 to 385 ft below the surface. Based on reported static water level depths of 0 ft below the surface in areas several miles south of the La Sal Mines Complex, it appears that surface waters are used in some areas. However, as noted above, the amount of radioactivity deposited on the ground, even near vents is very small, a small fraction of natural background (less than 1% as discussed in response to comment 2.3) and hence, the likelihood of penetration of shallow soil constituents is negligible.

San Juan County, Utah is a rural community with approximately 14,000 residents over an area of approximately 8,000 square miles (less than 2 residents per square mile) (USCB 2000). It is anticipated that local uses of groundwater near the La Sal Mines Complex will remain similar in the future.

### *6.2 Will discharges from mine ventilation system cause adverse effects to water quality?*

*Groundwater Quality*

As discussed in comment 6.1, above, discharges from the ventilation system will not affect groundwater/drinking water quality.

*Surface Water Quality*

As discussed in comment 3.8, above, since the incremental air concentrations are very small, airborne deposition is negligible even after 40 years of operation (see Section 3.0); therefore, the potential effect on surface water will be negligible and discharges from the ventilation system will not affect surface water quality.

### *6.3 Will uranium tailings at the White Mesa Mill be placed into a lined tailings facility?*

Uranium Tailings at White Mesa Mill (the "Mill") will be placed into double lined tailings cells. The design and operation of the tailings cells which receive La Sal Mines Complex ore are regulated by the Mill's Utah Division of Radiation Control ("DRC") License and DRC Groundwater Discharge Permit. Each new cell has been constructed with a double liner system – consisting of a primary 60 mil high density polyethylene ("HDPE") and secondary 60 mil HDPE flexible membrane liner ("FML") with a permeable HDPE geonet fabric leak detection system between the FML layers. The entire system is underlain by an additional geosynthetic clay liner of 0.2 inches of low permeability bentonite clay sandwiched between two layers of geotextile. The construction of each cell has been inspected and approved by DRC. The leak detection systems are monitored daily.

## 7.0 WILDLIFE

### *7.1 Will bioaccumulation of radioactivity cause significant effects to wildlife or livestock?*

The primary source of potential radiation exposure near vent holes would be from radon and radon daughter products from vent emissions. As discussed above, various international and national authorities have developed approaches to assessing radiation doses to non-human biota addressing both direct radiation and the soil and food chain uptake pathways, and the potential effects of such exposures (including for example, UNSCEAR 2008, IAEA 1992 and the U.S. DOE 2002 amongst others).

The procedure for evaluating risks to non-human biota involves estimating dose rates and comparing the estimated dose rates to reference dose rates below which no effects are expected on populations of plants and animals. The recent evaluation by UNSCEAR (2008) concluded that chronic dose rates of 100 μGy/h to the most highly exposed biota are unlikely to have an effect on populations of terrestrial biota. The dose rates around the La Sal Mine Complex from all sources of radioactivity are several orders of magnitude lower than the dose rates which UNSCEAR has determined would have no effect on vegetation or animals.

As noted previously, the amount of radioactivity deposited on soil, even very near a vent after 40 years of operation is very small and well within natural background levels. Thus, the radioactivity deposited on the ground due to mine activities represents an immeasurable change from current conditions, and in any event, the dose rate would be orders of magnitude below levels which have effects on non-human biota.

7.2 *Will release of radioactive and non-radioactive particulates from vents cause significant effects to wildlife?*

Radioactive Particulates

*As discussed above,* UNSCEAR 2008, IAEA 1992 and the U.S. DOE 2002 amongst others, have developed approaches to assessing radiation doses to non-human biota and evaluating risks by estimating dose rates and comparing the estimated dose rates to reference dose rates below which no effects are expected. The recent evaluation by UNSCEAR (2008) concluded that chronic dose rates of 100 μGy/h (10,000 μR/h) from all sources to the most highly exposed wildlife or plant life are unlikely to have an effect on these biota. As discussed in the response to Comments 1.1 and 2.4, above, the radiation dose to plants and animals living in the vicinity of the mine site would be indistinguishable from natural background levels. NCRP report No. 160 (2009) indicates the external gamma doses in the Colorado Plateau area are on the order of 0.05 to 0.08 μGy/h (i.e., 5 to 8 μR/h). The estimated dose rates around the La Sal Mine Complex from all sources of radiation combined are of the same order and hence several orders of magnitude lower than the dose rate, of about 10,000 μR/h, which UNSCEAR has determined would have no effect on vegetation or animals.

## 8.0 WORKER HEALTH AND SAFETY

8.1 *Will the proposed POA cause workers at the La Sal Mines complex to work in a health and safety environment that will have significant health effects?*

The La Sal Mine Complex is operated in compliance with the requirements established by the Mine Safety and Health Administration ("MSHA"), which establishes standards and inspects operational practices to ensure mine worker safety. There is nothing in the proposed POA that would impact the La Sal Mine Complex's ability to comply with applicable MSHA requirements.

MSHA inspects the La Sal mines at a minimum of once per quarter; however, occasionally MSHA will perform random inspections to ensure the Health and Safety of the Miners. The La Sal Mine Complex is currently in compliance with all applicable MSHA requirements.

8.2 *Will workers at the La Sal Mines Complex spread radioactive contamination into the La Sal community?*

The primary mechanism for workers to spread radioactive contamination into the community would be by bearing uranium ore dust on their persons.

Workers at the La Sal Mine Complex are provided with work clothes, either coveralls or over-shirts and pants, to be worn over their personal clothing during their work shift, and work boots to be worn in place of personal shoes during their work shift. They are also provided with other safety equipment such as hardhats, safety glasses, and gloves. Workers are assigned a locker in the mine's change house/locker room to store over-clothing, work boots, and other safety equipment after their work shift.

Workers are provided with showers in the locker rooms to remove any ore and dust particles before dressing in their personal clothes to leave the mine site after each shift.

Tools and equipment which have been used in the workings remain in the workings or are brought to the surface for repair and/or storage in the mine's maintenance or storage shops. Tools and equipment which have been used in the workings are not permitted to leave the site.

As a result of these measures, and the low grades of the uranium ores mined at the La Sal Mine Complex, the risk from any incidental radioactive contamination is considered to be negligible.

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**FIGURES**

**Figure 1**
**Uranium 238 Decay Series**

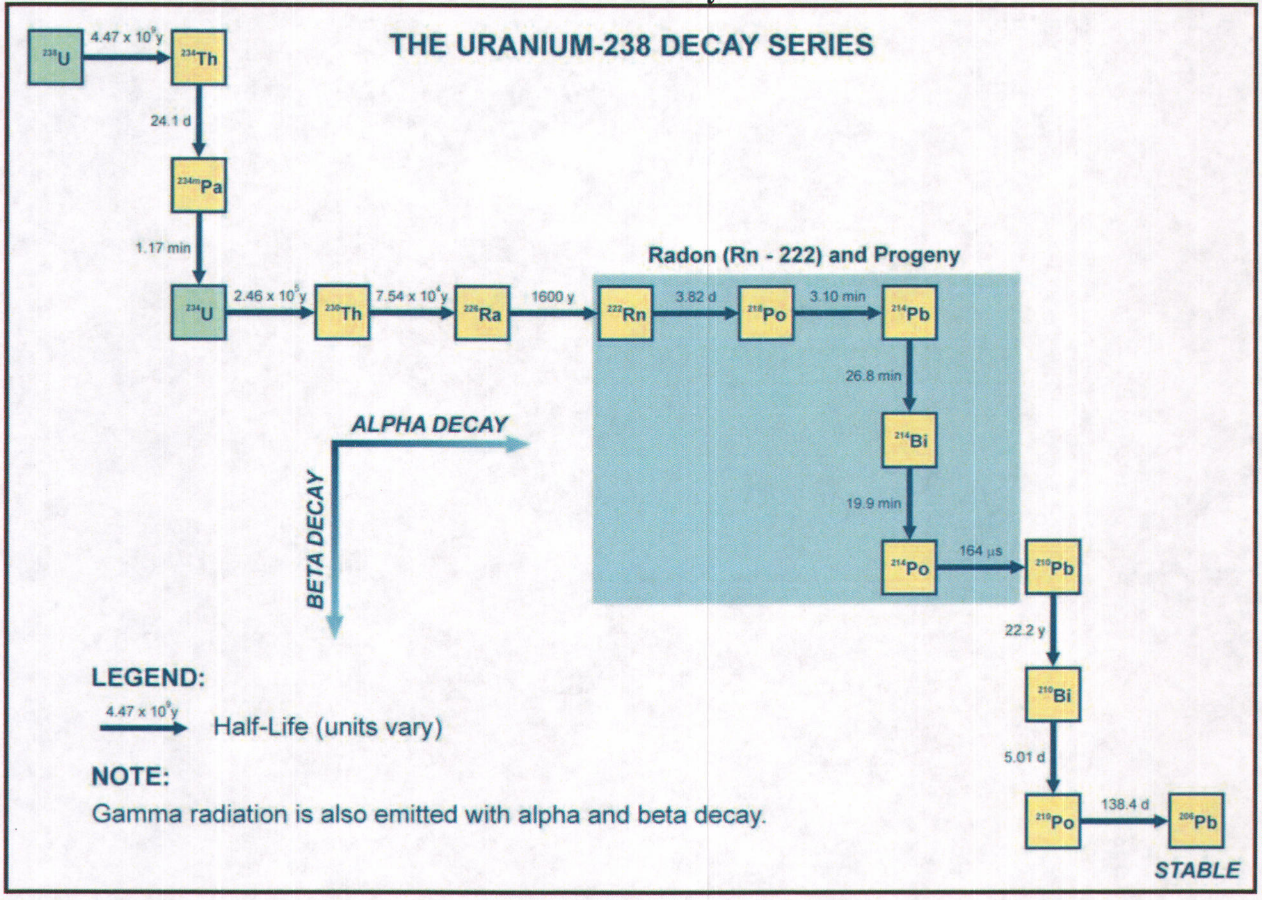
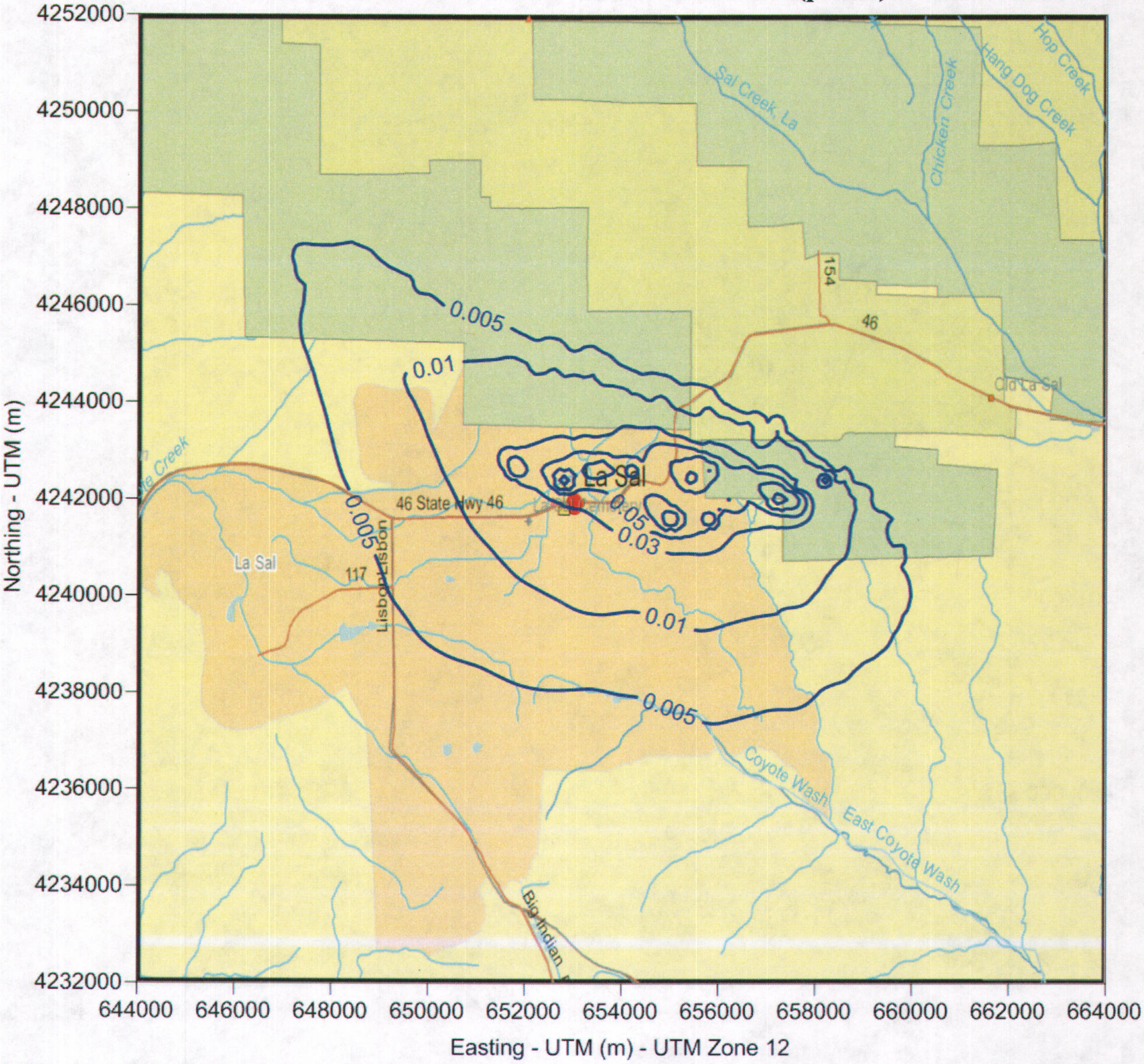
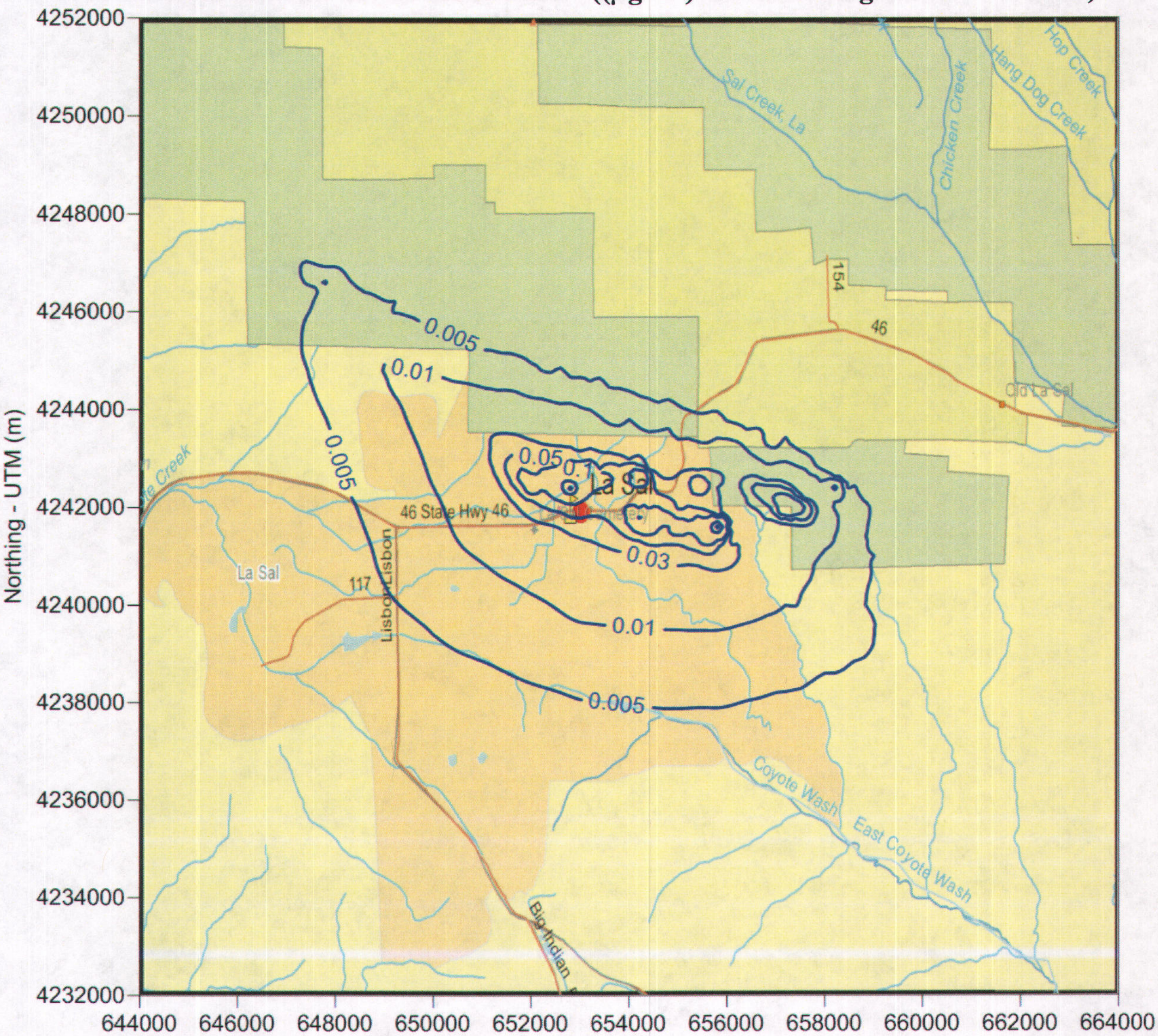


**Figure 2**
**Contour of Annual Radon Concentration* (pCi/L)**



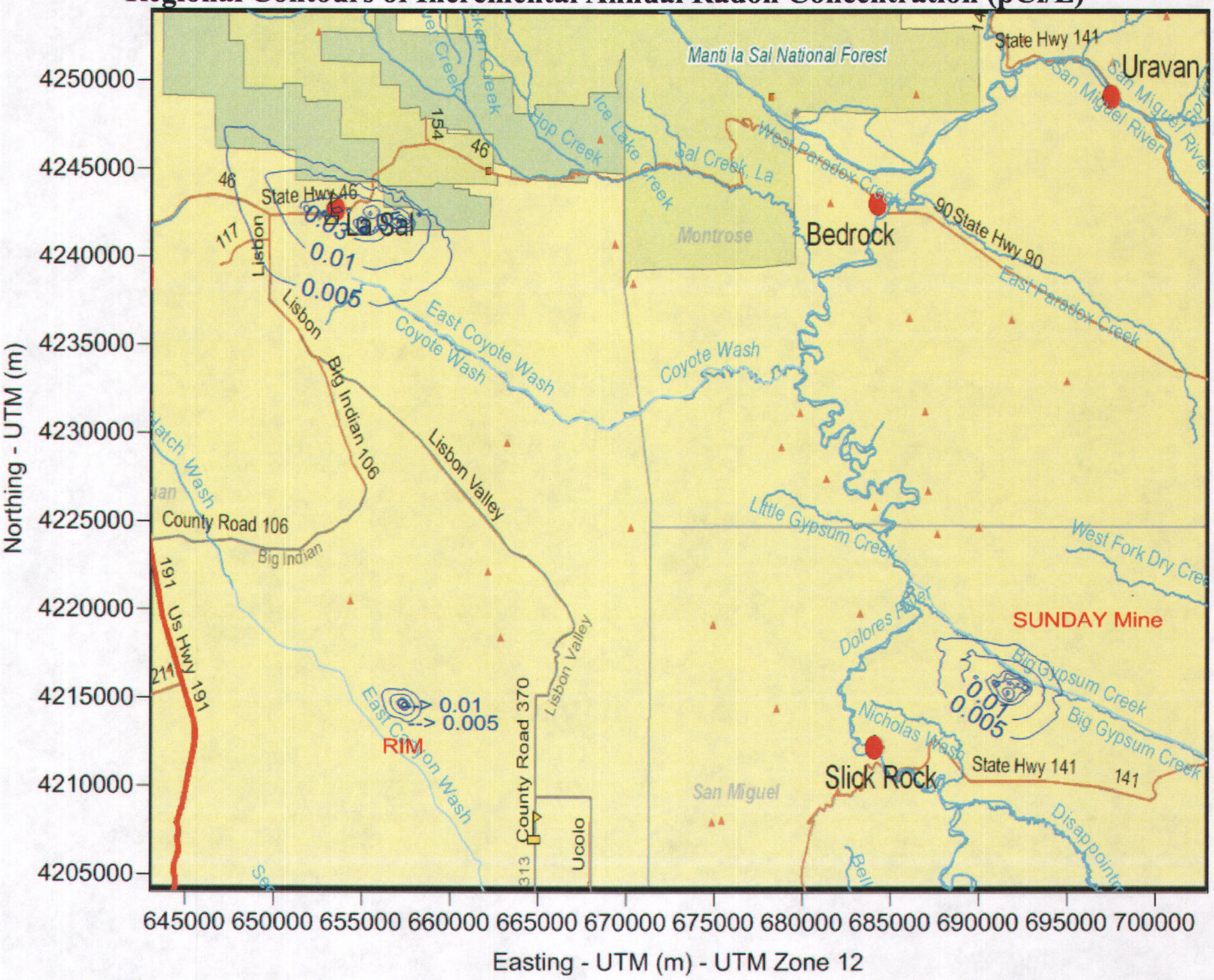

* The isopleths reflect the radon contributions from all mine vents.

**Figure 3**
**Contours of Annual Dust Concentration* (($\mu g/m^3$) Total Underground + Ore Pile)**




* The dust concentrations reflect all sources on surface and from mine vents.

**Figure 4**
**Regional Contours of Incremental Annual Radon Concentration (pCi/L)**



**ATTACHMENTS**

**ATTACHMENT A**
**SENES QUALIFICATIONS**

**SENES Consultants Limited**

*Specialists in Energy, Nuclear and Environmental Sciences*

## ENVIRONMENTAL EXCELLENCE IN THE NUCLEAR INDUSTRY

**SENES Consultants Limited** is a wholly Canadian-owned company that specializes in the fields of energy, nuclear, and environmental sciences.

Specialists in Energy, Nuclear and Environment Sciences (SENES) was founded in Canada in 1980. Since its inception, the company has participated in over 5,000 projects with over 50% of our work involving radioactivity or nuclear projects. We have worked in over 50 different countries throughout the world including North and South America, the Caribbean, Africa, Australia, Europe, Asia, the Middle East and the Far East. Our clients include private sector companies, government agencies, industrial associations, and international development organizations, World Bank, national and international financial institutions.

With over 30 years experience managing a variety of projects within the nuclear industry, SENES has developed a world-wide reputation for successfully delivering scientific expertise and providing an exceptional quality service to our clients.

SENES provides specialty services on a range of projects within the nuclear industry; projects pertaining to uranium mining and milling, uranium refineries, fuel fabrication, nuclear power generation and waste management. We also provide leadership and strategic advice to national and international agencies.

## Exceptional Service

The business philosophy of the firm is to provide an exceptional level of service to our clients while ensuring that our common interest in preserving the environment is enhanced. In the rapidly changing world in which we live, creative and innovative solutions are often required to resolve complex problems. We at SENES pride ourselves on staying in the forefront of technological advancement to allow us to continue to satisfy our clients' needs. We strongly believe that this attribute distinguishes us from our competitors.

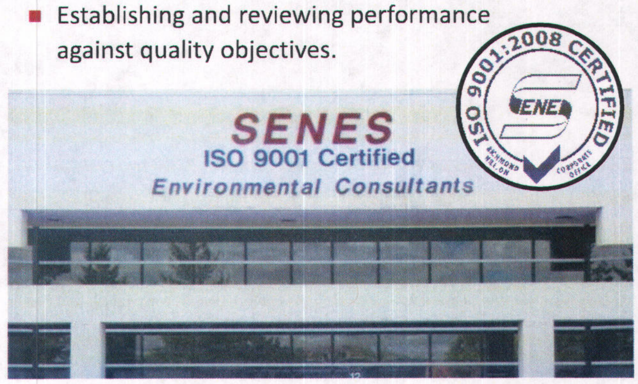
## Nuclear Industry Services

- ALARA Analysis and Audits
- Accidents and Malfunctions Assessment
- Aquatic and Atmospheric Environment
- Community Consultation and Communications
- Data Management and Statistical Analysis
- Dose Reconstruction and Epidemiological Support
- Due Diligence and Liability Assessment
- Emergency Preparedness Plans/Audits
- Energy Planning
- Environmental Impact Assessment
- Environmental Management
- Environmental Monitoring and Radiological Surveys
- Radioactive and Hazardous Waste Management
- Radioactivity and Dose Assessment, ALARA
- Regulatory Support and Licensing
- Remedial Actions and Decommissioning
- Risk Assessment (Human Health and Ecological)
- Waste Management and Decommissioning

## Our ISO 9001 Commitment

SENES provides an exceptional level of service to our Clients with work that is scientifically objective and environmentally responsible. We are committed to:

- Meeting Client requirements and expectations;
- Continually improving the effectiveness of our Quality Management System;
- Following a systematic approach to project management;
- Complying with contractual, internal and regulatory requirements; and,
- Establishing and reviewing performance against quality objectives.



The strength of SENES is a direct reflection of the extensive knowledge and experience of our staff.

SENES provides a range of services including the provision of expert advice on specific environmental issues; baseline characterization studies; preparation of environmental and risk assessments, site investigations, radioactivity and health physics, development of remedial action plans, air and water quality assessment and modeling, decommissioning and closure plans, and development and implementation of public participation programs.

Below is a cross section of projects intended to illustrate our range of experience within the Nuclear Industry.

## The Nuclear Fuel Cycle

### Uranium Mining and Milling:

SENES has been involved in all aspects of uranium mining and milling across Canada, the U.S.A. and internationally for over 30 years. SENES experience includes:

- Tailing site selection and management studies
- Assessment of worker exposures and development of radiation protection plans
- Environmental pathways and dose assessment
- Dose reconstruction and epidemiology
- Human health and ecological risk assessment
- Accidents and malfunctions assessment
- Review of relevant legislation and regulations
- Radiation Health Physics support
- Decommissioning planning
- Environmental monitoring
- Audit/Due Diligence reviews
- Baseline monitoring
- Environmental assessment
- Regulatory support

### Uranium Refining and Conversion, Fuel Manufacturing:

Refining purifies yellow cake from mines and conversion facilities convert purified uranium trioxide to uranium hexafluoride and uranium dioxide; products required in the production of fuel for light water and CANDU-type heavy water nuclear reactors.

SENES experience for refining and conversion clients includes:

- Environmental monitoring
- Environmental assessment
- Air dispersion and water quality studies
- Acoustic assessment
- Radiation dose assessment and radiation protection
- Human health and ecological risk assessment
- Accidents and malfunctions assessments
- Community consultation
- Regulatory and licencing support
- Auditing

SENES has provided support to suppliers of fuel bundles for operators of CANDU heavy water nuclear reactors, the operation consists of producing fuel pellets from natural uranium dioxide and the manufacturing and assembly of reactor fuel bundles. SENES experience includes:

- Human health and ecological risk assessment
- EA for the expansion of fuel bundle production, including enriched uranium fuel
- Accidents and malfunctions assessment
- Regulatory and licensing support
- Auditing

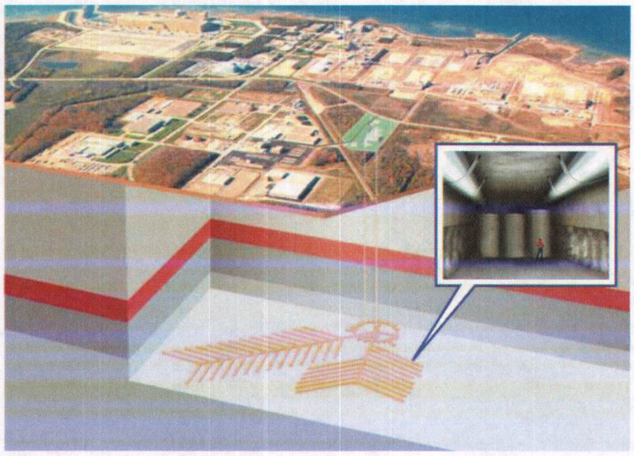
## Nuclear Power

SENES has provided support to nuclear power plant sites in Canada, and has provided advice and assessment for nuclear power plants in Romania, completed due diligence on a number of nuclear power plants in the United States and updates to IAEA's NUK Packs program for evaluation of Health Effects of air emissions from nuclear power plants.

SENES experience includes:

- Review of the effects of the stations on the biophysical environment surrounding the station
- Environmental monitoring
- EA's for the return to service, refurbishment and new build nuclear power plants
- Human health and ecological risk assessment
- Thermal effects assessment
- Radiation dose assessmentS
- Studies to support EA's of used fuel dry storage facilities
- Accidents and malfunctions assessments

## Waste Management



**Deep Geologic Repository (DGR):**

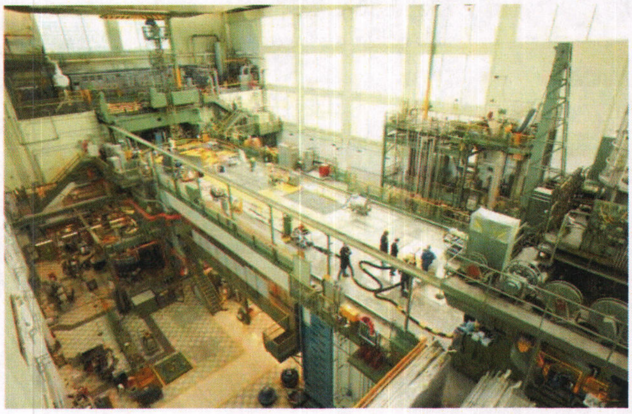
Ontario Power Generation is studying the possibility of permanent disposal of its low and intermediate waste in a deep geological repository (DGR). The construction and operation of a DGR and emplacement of waste in a DGR is a complex project. SENES experience includes:

- Evaluation of site storage
- Human health and ecological risk assessment
- Pre and post closure safety assessment
- ALARA assessment
- Exclusion Zone assessment

**National Research Universal (NRU) Reactor Long-term Management Project:**

The NRU Reactor at Chalk River Laboratories, owned and operated the by the Atomic Energy Control Limited (AECL) is a versatile research reactor that has been operating since 1957. SENES experience includes:

- Technical studies including atmospheric modelling, risk assessment and accident analysis in support of EA
- Accidents and malfunctions assessment
- EA for new Used Fuel Dry Storage System
- Strategy development for engaging the federal regulator in the project



## Strategic Advice and Planning

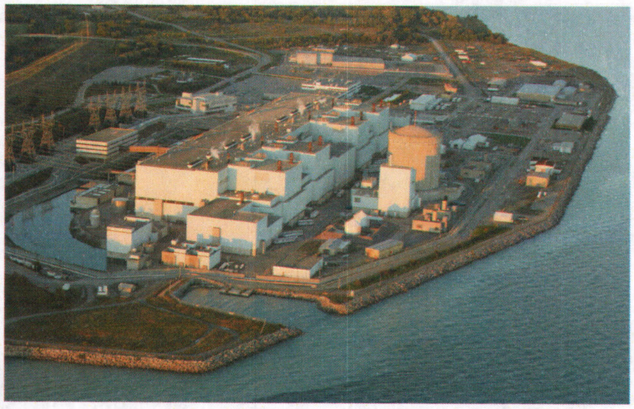
**Ontario Power Authority:**

Responsible for ensuring that electricity needs for the province of Ontario are met. SENES experience includes:

- Methods to assess the impacts on the natural environment of generation options
- Supplementary environmental impacts for the integrated power system plan
- Environmental analysis of transmission projects

## Feature Project

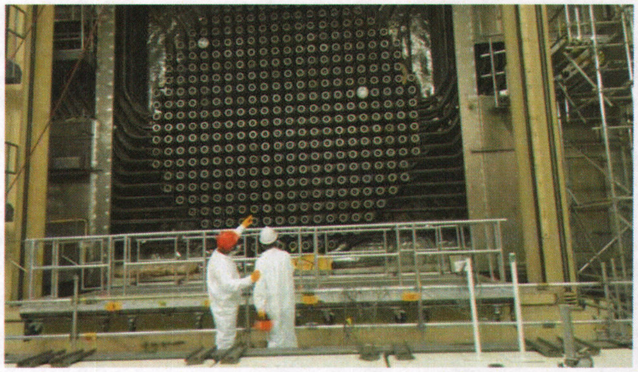
### Darlington Nuclear Generating Station:

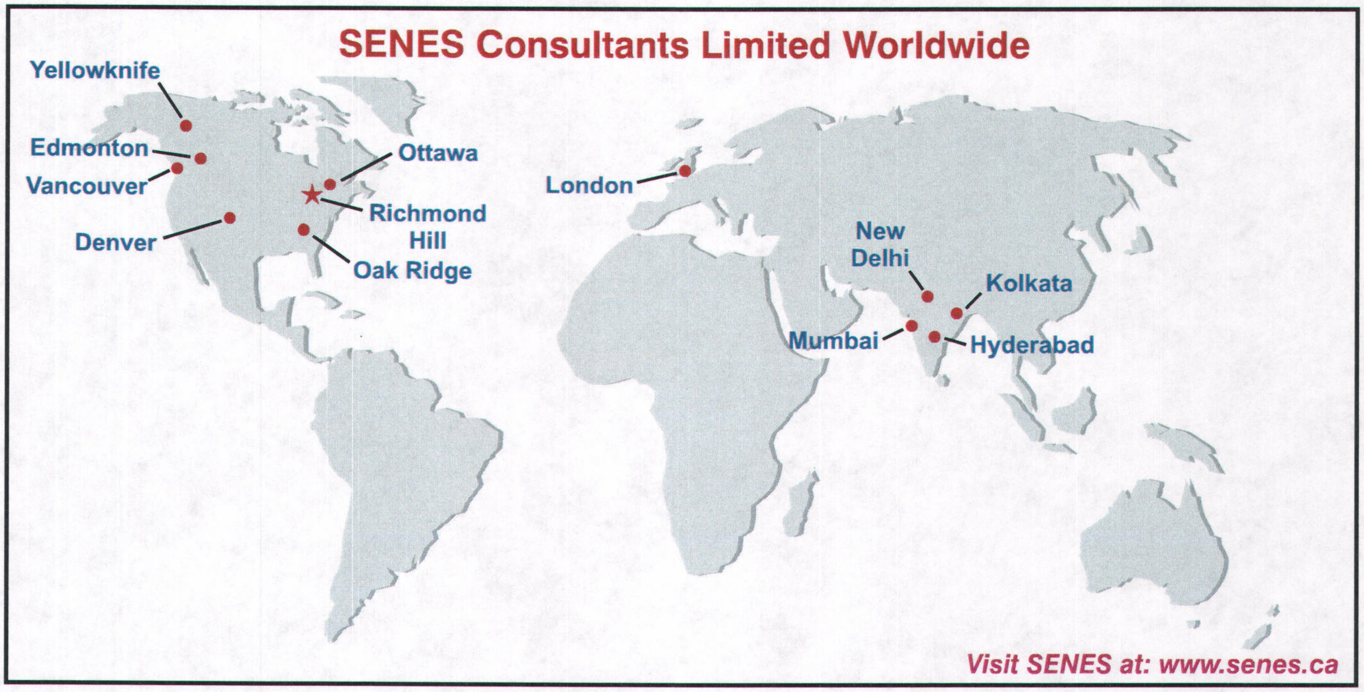


Located in Ontario, Canada, Darlington generating station operates 4 CANDU reactors providing a total output of over 3,500 MW. In 2006 planning and regulatory approvals commenced for the construction and operation of up to four new nuclear reactors at the Darlington Station which will add up to 4,800 MW of electrical capacity.

SENES experience includes:

- Accidents and malfunctions assessment
- Air dispersion studies
- Acoustic assessments
- Aquatic studies
- Environmental monitoring
- Evaluation of health effects of worker and public
- EA for new reactor development
- EA for refurbishment and continued operation
- EA for Used Fuel Dry Storage Facility
- Expert testimony at public hearings
- Radiation dose assessment



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# ATTACHMENT B
# REASONABLY FORESEEABLE FUTURE ACTIONS

According to Denison's understanding, projections of possible future uranium production from the deposits in the review area are dependent on estimation of future $U_3O_8$ and $V_2O_5$ market prices. From a low of under $10 per lb $U_3O_8$ around 2000, to over $130 per lb $U_3O_8$ in 2007, market prices for $U_3O_8$ have varied widely in the past decade. Likewise, $V_2O_5$ prices have ranged from around $2 per lb $V_2O_5$ to over $20 per lb. Current prices have settled around $50 - $60 per lb for $U_3O_8$ and $6 - $7 per lb for $V_2O_5$.

Prices for $U_3O_8$ over $100 per lb a few years ago were unsustainable and influenced by speculative buying. Conversely, prices under $40 per lb are generally recognized as being inadequate to sustain, let alone support increases, existing production. Market analysts project $U_3O_8$ prices for the next five to 10 years to be in the range of $55 to $65 per lb $U_3O_8$. In the projected range of $55 to $65 per lb, few new projects or reactivations of historical projects in the review area can be forecast. In addition, to provide a basis for analysis of potential cumulative effects, a number of currently known projects are discussed below.

A number of historical projects which are being proposed for reactivation are within the review area. Two important elements must be considered:

- If $U_3O_8$ prices stay at or below the current level of ~$55 per lb $U_3O_8$, considerable uncertainty exists as to when, or if, these projects might enter production, and
- If a number of projects start up in the review area, these will not be fully incremental to existing production. For example, Denison is mining at the Beaver Mine and proposes to activate the Redd Block mine in coming years; production from Redd Block is not fully incremental to current production at Beaver, but rather would "replace" production in the Beaver area as resources are exhausted.

The Denison White Mesa Mill currently processes about 120,000 tons of ore, grading about 0.21% $U_3O_8$, annually from mines in the review area and produces 400,000 to 500,000 lbs of $U_3O_8$ concentrate from these sources at the Mill. Energy Fuels' proposed Pinon Ridge Mill will have an initial licensed capacity of 175,000 tons of ore year and will be licensed to recover up to 850,000 lbs $U_3O_8$ per year. This is licensed capacity, and sustained production at the design rate may not be consistently sustainable at uranium prices in the low end of the projected range for the next several years. If Denison and Energy Fuels are both able to develop and mine sufficient ore to feed the two processing mills from the review area, annual ore feed could reach a combined level of 300,000 to 400,000 tons containing on the order of 1.2 to 1.7 million lbs of $U_3O_8$ annually. Again, the premise is that all of the ore to be mined to reach these production levels will be sources from within the review area, which is highly speculative presently.

Projects that are currently known and which would be expected to be contributors to the total production throughput described above include:

- Denison's La Sal, Beaver, and Pandora mines – currently operating (subject of the current amendment process);
- Denison's Redd Block mine – in planning stage;
- Energy Fuels' Energy Queen – previously developed mine presently on standby and pending reactivation;
- Laramide Resources' La Sal II mine in T29½S R24E Utah;
- Jay Bird Mine and related properties in T47N R20W Colorado;
- Uranium One's Velvet mine in T31S R25E Utah;
- Denison's Rim Mine in T31S R25E Utah;
- Denison's Sunday Mines Complex in T44N R18W Colorado;
- Various mines now on standby on DOE leases held by Cotter Corp., Energy Fuels, and others generally in T46N R17W Colorado;
- Energy Fuel's Whirlwind mine and associated project in T51N R20W Colorado;
- Various other small mines which are currently permitted to operate but produce only small quantities intermittently from within the review area.

The next tier of possible producing projects are in areas of past mining or areas which have known resources, but which have not been previously developed. These possible projects include:

- Yellow Circle mines in T28S R23E;
- Pine Ridge adjoining Denison's Pandora area on the east;
- Wray Mesa and Hop Creek generally in T28S and 29S R26E;
- Past producing mines such as Deremo, Wilson, Silverbell, Calliham, Dunn, etc. along the Utah-Colorado border west and northwest of Egnar, Colorado;
- Various small residual resources in the general Slick Rock and Joe Davis Hill areas Colorado, generally in T43N and 44N R18W;
- Numerous historical mines on a combination of mining claims and DOE Leases located generally in the area of T47N and 48N R17W.

While possible sources of future production can generally be identified, projecting sustainable rates of production is highly conjectural. For purposes of a cumulative impact analysis, speculative ranges of production have been projected as follows (again, it should be specifically noted these rates are not fully incremental and will in some cases be "replacement" of production from depleted mines, hence an extremely conservative assessment is generated if projected rates are assumed).

| | |
|---|---|
| • La Sal Complex: | |
| • (La Sal Complex, Redd Block, Pine Ridge, etc.): (per the Plan of Operations) | 100,000 tons per year |
| • Energy Queen: | 60,000 tons per year |
| • Sunday Complex: | 50,000 tons per year |
| • Whirlwind: | 50,000 tons per year |
| • Rim Mine: | 15,000 tons per year |
| • La Sal II: | 50,000 ton per year |
| • Cotter and Energy Fuels and other DOE Leases and Uravan area: | 75,000 tons per year |
| • Velvet: | 60,000 tons per year |
| • Wray Mesa/Hop Creek area: | 40,000 tons per year |
| • Other mines: | 25,000 tons per year |

In aggregate this projection presents possible production approaching 500,000 tons annually which could yield up to 2.5 million lbs $U_3O_8$. This conjectural scenario is double current projected near term production (assuming Energy Fuels starts Pinon Ridge in the next few years). As noted previously, this production level is a maximum since much of the possible production would replace current and near term production that is depleting known resources.

Undiscovered resources, or known resources which have not been fully quantified, could add longevity to the projected production estimate, but these possible sources would not be expected to add to near term production given the lead times required for permitting and mine development.

# ATTACHMENT C
# INDIRECT EXPOSURE PATHWAYS

MILDOS-AREA Version 3.07 (ANL 2008) was applied to model a generic exposure as a result of airborne uranium ore dust and to provide a detailed breakdown of dose by direct and indirect pathways (e.g., ingestion). The pathways considered in the MILDOS-AREA model include inhalation; groundshine and cloud immersion; and ingestion of vegetables, meat and milk.

The model was used to establish the dose to a receptor continually exposed to 1 ng/m$^3$ airborne uranium ore dust over a 40 year period. The receptor dose evaluated in the 40$^{th}$ year of exposure to these conditions and was inclusive of 40 years of ore dust deposition on the ground as a result of a continuous 1 ng/m$^3$ exposure.

MILDOS-AREA is not capable of accepting air concentrations directly as the radioactive source, so it was necessary to estimate a point source that would produce approximately 1 ng/m$^3$ uranium ore dust air concentration at the receptor which was placed in the same location as the point source. The source term applied was a point source producing 1E-06 Ci/y of ore dust in secular equilibrium and therefore included dose contribution from each of U-238, Th-230, Ra-226, and Pb-210. The source term was inputted into MILDOS-AREA with stack velocity of 0 m/s; this source term produced an airborne concentration of 3.27E-04 pCi/m$^3$ at the receptor which was co-located with the point source.

This airborne concentration of 3.27E-04 pCi/m$^3$ was determined to be approximately 1 ng/m$^3$ using the specific activity of 1 g natural uranium = 0.677 μCi (U.S. NRC, 10 CFR 20, Appendix B), such that natural uranium is defined as 48.6% U-238, 49.2% U-234, and 2.2% U-235. Traditionally, it is assumed that 50% of the activity of the natural uranium is attributed to each U-238 and U-234 with contribution from U-235 considered to be negligible, thus, an airborne activity of 0.339 μCi/m$^3$ U-238 would be equal to 1 g/m$^3$ of natural uranium or 3.39E-04 pCi/m$^3$ = 1 ng/m$^3$. The contributions from the U-235 chain not being included in the calculations is consistent with the MILDOS-AREA model, which according to Strenge and Bander 1981, *"Radionuclide releases are defined for each source for particulates and radon gas. The $^{238}$U decay chain assumed to be the only significant source of radiation for uranium-milling operations. The contribution from the $^{235}$U chains is less than 5% of that from the $^{238}$U chain."*

In the case of uranium ore dust, all associated progeny are assumed to be in equilibrium with uranium, therefore, the source term included 1E-06 Ci/y from Th-230, Ra-226, and Pb-210 in addition to the contribution from U-238. With the use of this source, MILDOS calculations determine a concentration of 3.29E-04 pCi/m$^3$ in Year 40; this airborne concentration was considered an adequate approximation for 1 ng/m$^3$ of uranium ore dust (3.39E-04 pCi/m$^3$).

The dose was estimated to an adult, teenage, child, and infant as a result of the inhalation, groundshine and cloud immersion; and ingestion of vegetables pathways. The ingestion of vegetables was based on agricultural production for the state of Utah provided in the Table 4.8 of

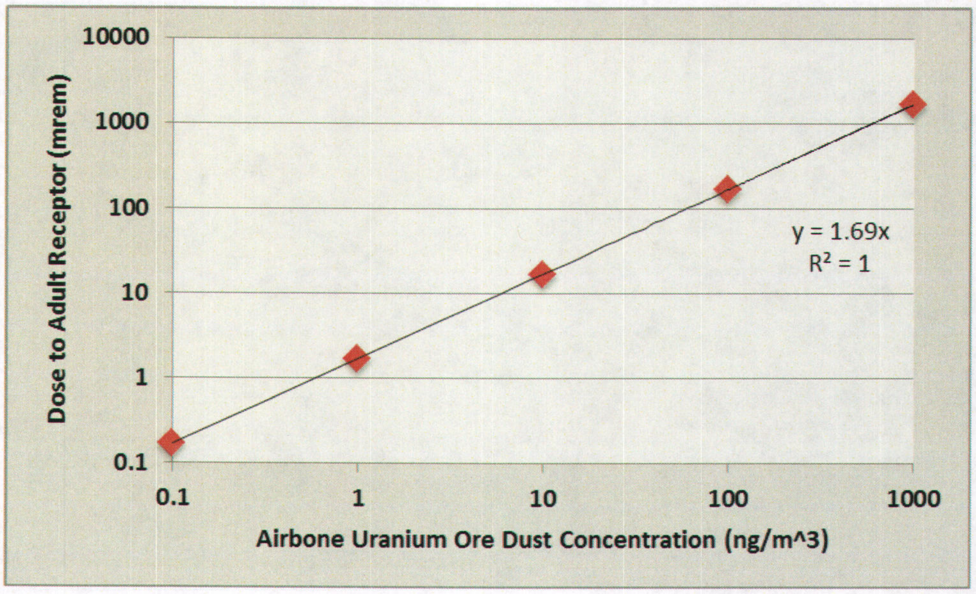
ANL 1996. Exposures included the contribution of 40 years of ground deposition as a result of an air concentration of 3.29E-04 pCi/m$^3$, determined to be 1953 pCi/m$^2$ for U-238 and Th-230, and 1938 pCi/m$^2$ for Ra-226 and Pb-210. Table B.1 below provides the total and individual pathway doses calculated for each of these four receptors.

**Table B.1 Dose to Receptor in Year 40**

| Age Group | Inhalation (mrem/y) [% of Total] | Groundshine (mrem/y) [% of Total] | Cloudshine (mrem/y) [% of Total] | Ingestion of Vegetables (mrem/y) [% of Total] | Total (mrem/y) |
|---|---|---|---|---|---|
| Infant | 3.37<br>[90] | 0.36<br>[10] | 5.2E-08<br>[0] | 0<br>[0] | 3.73 |
| Child | 1.71<br>[77] | 0.36<br>[16] | 5.2E-08<br>[0] | 0.15<br>[7] | 2.22 |
| Teenager | 1.18<br>[66] | 0.36<br>[20] | 5.2E-08<br>[0] | 0.24<br>[14] | 2.22 |
| Adult | 1.17<br>[70] | 0.36<br>[22] | 5.2E-08<br>[0] | 0.14<br>[8] | 1.66 |

The generic value of 1 ng/m$^3$ (0.001 µg/m$^3$) can be applied to any determined air concentration as a result of mining or milling activities. Using the MILDOS-AREA model, doses to adult receptors were determined for airborne uranium ore dust over several orders of magnitude and were found to increase linearly with increased air concentration. This is demonstrated in a graph of the estimated doses as a function of airborne concentrations as shown below in Figure B.1.

**Figure B.1 Dose Increase to an Adult Receptor at Year 40 as a Result of Increased Airborne Uranium Ore Dust Concentration**



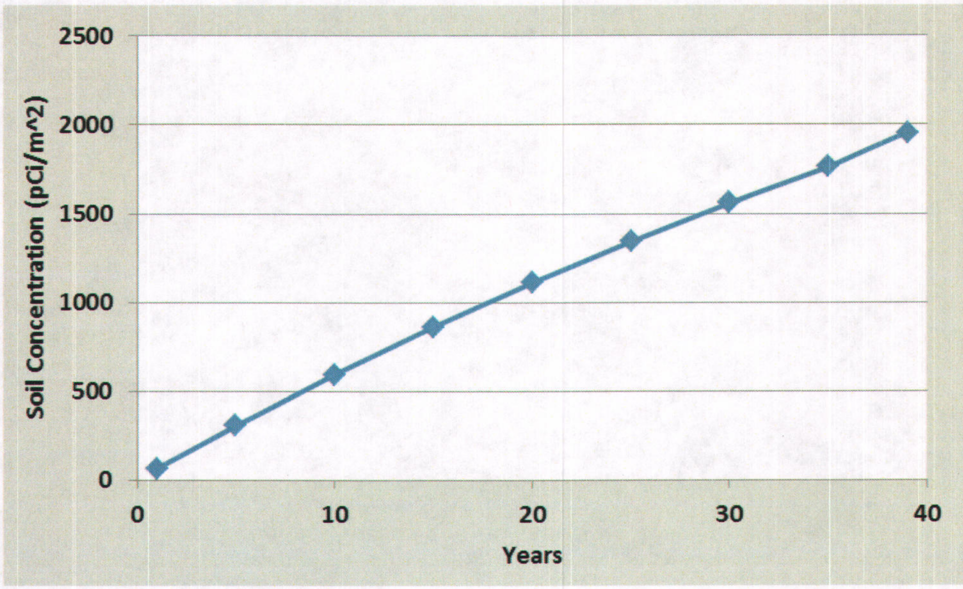

With the application of the relationship determined by this exercise, the dose to an adult receptor as a result of an airborne uranium ore dust concentration after 40 years deposition can be determined:

$$\text{Dose (mrem)} = 1.69[\text{Ore Dust}]$$

Where [Ore Dust] = uranium ore dust concentration in ng/m$^3$

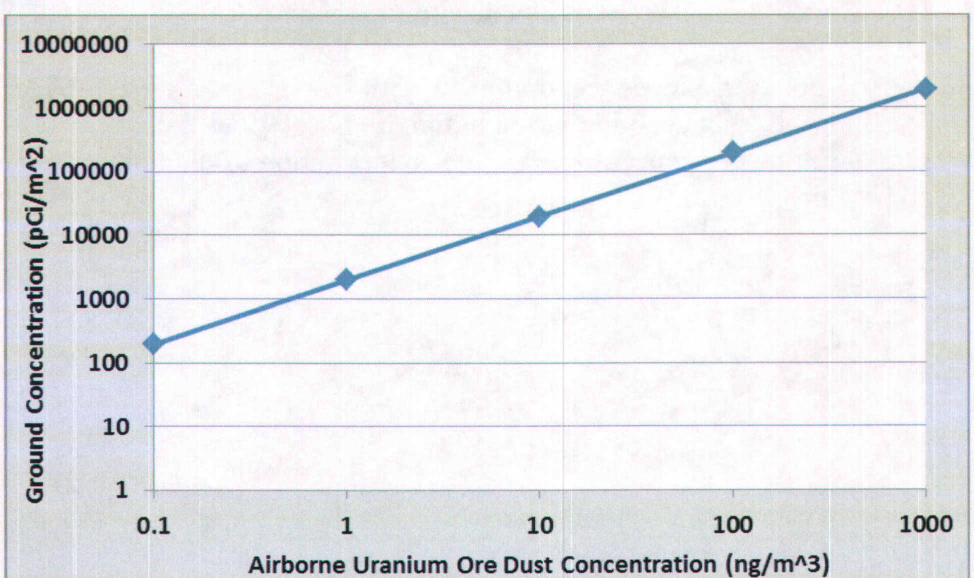
The concentration of uranium ore concentration in soil was also computed. The following figure, Figure B.2, shows the concentration of uranium ore in soil over time from 1-39 years of a continuous 1 ng/m$^3$ airborne ore concentration. The concentration of uranium in soil at 39 years was calculated to be 1953 pCi/m$^2$.

**Figure B.2 Soil Concentration of Uranium Ore Over Time as a Results of 1 ng/m$^3$ Airborne Contamination**




The deposition rate of the uranium ore changes linearly with air concentration as well. Figure B.3 shows the changes in soil concentration at the 40 point with varying airborne ore concentrations, which increase evenly with increasing airborne concentration.

**Figure B.3 Ground Concentrations of Uranium at 40 Years for Different Airborne Uranium Concentrations**



## References

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## ATTACHMENT D
## BIOACCUMULATION OF URANIUM IN SOIL HORIZON

The concentration of uranium in soil at 39 years was calculated to be 1953 $pCi/m^2$ (See Attachment C). The 2,000 $pCi/m^2$ of deposited uranium after 40 years converts to 3,000 $\mu gU/m^2$ (or 3 $mgU/m^2$, i.e., 2,000 $pCi/m^2$/0.677 pCi/µgU (specific activity of uranium)). This was based on an assumed 1 $ng/m^3$ uranium ore dust air concentration. The predicted concentrations of uranium dust concentrations (Table 1) show that the maximum modelled uranium in air at various receptors was 3E-4 $\mu g/m^3$ or 0.3 $ng/m^3$. Thus, the deposited uranium would be correspondingly lower at:

$3\ mgU/m^2 \times 0.3 = 0.9\ mgU/m^2$

If this became mixed in the upper soil horizon (5 cm), the resultant soil uranium concentration would be:

$0.9\ mgU/m^2/0.05\ m = 18\ mgU/m^3 = 0.018\ gU/m^3$

Assuming a soil density of 1.6 $g/cm^3$ (1.6E6 $g/m^3$), the incremental concentration of uranium in soil would be:

$0.018\ gU/m^3/1.6E6\ g/m^3 = 0.011 \times 10^{-6} = 0.011$ ppm.